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A NEW METHOD OF HETEROCHROMATIC PHOTOMETRY

BY C. E. FERREE AND GERTRUDE RAND

Bryn Mawr College

In a former paper[1] it was stated that a satisfactory method of photometry should combine the following features. (1) It should enable us to detect small differences in luminosity and to reproduce our results for a given observer with a small mean variation and for a number of observers with a comparatively small mean variation. That is, the method should possess an adequate degree of sensitivity, and should give results with a satisfactory degree of reproducibility.[2] (2) It should be known either to possess of itself logical sureness of principle or its results must agree in the average with those of some method which can be shown to possess this sureness of principle. Methods having these features have been developed for the photometry of colorless light. The problem for the photometry of colored light, however, has presented great difficulty.

The methods for the photometry of colored light may be grouped under two headings: the direct and the indirect methods. In the former class we have the method of direct

[1] Ferree, C. E. and Rand, Gertrude, 'A Preliminary Study of the Deficiencies of the Method of Flicker for the Photometry of Lights of Different Color,' *Psychol. Rev.*, 1915, 22, pp. 110–162.

[2] It is scarcely needful to point out in this connection that the method should give results with a satisfactory degree of reproducibility for observations separated both by short and by long intervals of time.

comparison or as it is sometimes called the equality of brightness method. This method is generally accredited with sureness of principle but it is deficient on the side of sensitivity and reproducibility when lights differing in color value are compared.[1] Of the latter class the method of flicker has received the greatest amount of attention and has been the most favored. But in our former paper it was shown (1) that the method of flicker, so far as it has been developed up to the present time, does not possess of itself the sureness of principle needed to meet the requirements of a satisfactory method; and (2) that as yet its results have not been found to agree on the average with those of any method which can be shown to have this sureness of principle. It was also stated that in a later paper a method of photometry would be described which possesses approximately as high a degree of sensitivity and of reproducibility as the method of flicker and gives results which agree very closely on the average with those obtained by the equality of brightness method, much more closely than results obtained by the method of flicker. It will be the purpose of this paper to give a brief description of this method. It was first used by the writers in connection with work in color sensitivity for the purpose of detecting small changes on the illumination of a room by daylight.[2] Although not so convenient perhaps as the equality of brightness method for many of the purposes for which photometry may be used, for this work the method did not present any great amount of difficulty, and it proved to be much more sensitive than the equality of brightness method. The equality of brightness photometers of the Sharp-Millar type, for example, are very insensitive for the determination of the illumination of a room by daylight, because the standard field

[1] *Loc. cit.*, pp. 114–115.

[2] See Ferree, C. E. and Rand, G., 'An Optics-Room and a Method of Standardizing Its Illumination,' *Psychol. Rev.*, 1912, 19, pp. 364–373; Rand, G., 'The Effect of Changes in the General Illumination of the Retina upon Its Sensitivity to Color,' *ibid.*, pp. 463–490; 'The Factors that Influence the Sensitivity of the Retina to Color: A Quantitative Study and Methods of Standardizing,' *Psychol. Rev. Monog.*, 1913, 15, No. 62, pp. 79–166; see also Ferree, C. E., 'Tests for the Efficiency of the Eye Under Different Systems of Illumination and a Preliminary Study of the Causes of Discomfort,' *Trans. Ill. Eng. Soc.*, 1913, 8, p. 51.

illuminated by the tungsten lamp is deep orange in color, while the comparison field illuminated by daylight is clear white. This difference in color tone makes the judgment of equality of brightness difficult to make, and renders the instrument extremely insensitive for daylight work.

So far as the type of judgment is concerned, the method we are about to describe is in reality an equality of brightness method but it has the important advantage that the observer is never required to judge impressions differing in color quality. In making a photometric balance by this method, the feature is thus eliminated which has from the beginning of the work of measuring light intensities rendered the equality of brightness method difficult of application to heterochromatic photometry. Because of this factor we have at the suggestion of certain photometrists undertaken to work out the principle on which the method is based in a way that will be of general service to the work in heterochromatic photometry and to secure data on the points in terms of which a verdict is rendered for every method of photometry, namely, the sensitivity and precision of the method, and the agreement of its results with those obtained by the equality of brightness method.

The method is based upon the extreme sensitivity of the peripheral retina to brightness contrast, especially to the induction of black by a white screen. Not only is the peripheral retina extremely sensitive to brightness contrast, but, which is the crucial point of the method, very small changes in the illumination of the contrast screen produce a change in the amount of the contrast. That is, for any part of the retina, for example, the amount of contrast induced by the surrounding field upon a contrast stimulus increases with decrease of illumination. In the peripheral retina we have an extreme case of this. In this part of the retina very small changes of illumination indeed are required to produce a noticeable change in the amount of contrast induced, especially when the surrounding field is white and the stimulus is a gray of the proper brightness.

The apparatus needed for the method consists of a vertical

screen 60 × 50 cm. with an opening 15 mm. in diameter midway between top and bottom and 16 cm. from one edge, a motor to carry the measuring discs, and a photometer bar. The surface of the screen is covered with Hering mat white paper, or preferably with a paper overlaid with magnesium oxide deposited from the burning metal. This screen is graduated in the horizontal meridian from the center of the 15 mm. opening. Over the opening between the white covering and the screen is placed the gray which is to serve as the contrast-stimulus. Nos. 3–5 of the Hering series of standard gray papers were found to serve this purpose best for the intensities of light we used in the work the results of which are given in Table I. The measuring discs were made up of a sector of the same gray as was used for the contrast-stimulus and a sector of black, the varying proportions of which produce the match which is needed between the stimulus gray darkened by contrast and the measuring disc. The measuring disc was carried by a motor the shank of which is at one end of the screen and normal to it. When in position, the inner edge of the disc extends approximately to the 20° point of the graduations, and is about 3 cm. in front of the screen.[1] Immediately in front of the disc and 25° from the center of the stimulus-opening to the temporal side is placed the fixation-point.[2] The photometer bar was placed in a

[1] The measuring disc was placed this distance in front of the screen partly to give freedom of rotation but primarily to eliminate any induction by the screen on the disc. That induction is not present in any considerable amount under the conditions described above, is evident from the following considerations, (*a*) It is not directly detectable by the eye; and (*b*) a very high sensitivity is attainable by the method which could not be the case were induction present to any degree, for if it occurred in amounts great enough to influence sensation, the effect would obviously be to lower the sensitivity of the method. That there has been no lowering of sensitivity from this cause is rendered probable by the fact that approximately as small differences can be detected for lights differing in color quality as can be detected by Lummer-Brodhun photometers of the most improved type when the lights compared are of the same color quality.

[2] Care should be taken not to place the fixation-point so far from the stimulus-opening that the color used is seen of a different quality at this point than at the stimulus-opening. If this should occur for any color when the fixation is at the 25° point, a lesser excentricity should be chosen. The sensitivity of the contrast-effect to change of illumination is not lessened to any considerable extent, for example, by taking a 20° instead of a 25° fixation-point. We have found the 25° point to be very

plane normal to the screen midway between the stimulus-opening and the fixation-point. The contrast-stimulus and the measuring disc thus receive equal amounts of light from the source to be measured.

In Fig. 1 is given a picture of the apparatus in the rough form in which it is at present used. At *S* is shown the screen which is illuminated in turn by the standard and comparison lights; at *B* the photometer bar; at *D* the measuring disc; at *L* the lamp to be photometered; at *M* the mouthboard;

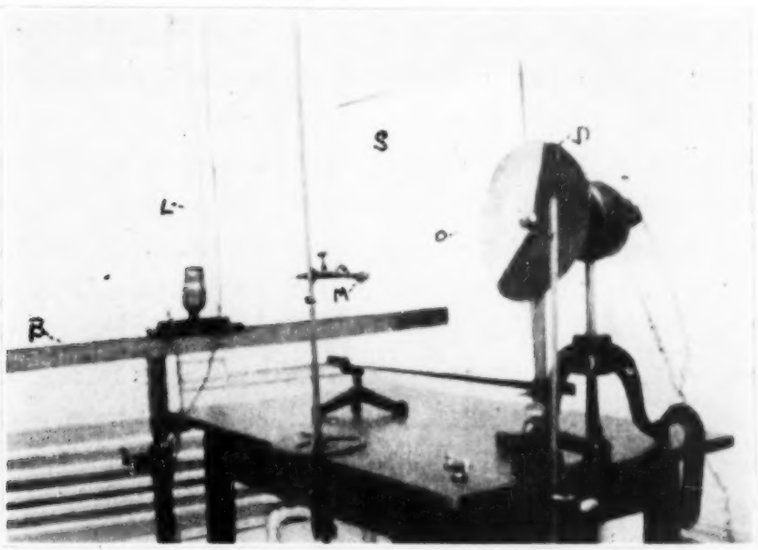

FIG. 1

and at *O* the opening filled with gray which is darkened in graded amounts by induction from the screen *S* as the amount of light received by it from the lamp *L* is varied. The screen *S* is supported by short rods screwed into heavy tripod bases. In order to provide for adjusting the height of the screen above the table the frame of the screen is fastened to the supporting rods by means of a collar and set screw. On the upper edge of this frame is attached a device for lining up the eye with the stimulus-opening *O*. This device consists of the following parts: A vertical arm carrying at its lower end a small circle 15 mm. in diameter extends

satisfactory, however. For a fixation-point we used a black knot on a gray thread, stretched from a point on the screen *S* to a rod in front and on the opposite side of the measuring disc.

down to the level of the stimulus-opening *O*. Attached to the vertical arm just above this circle is a horizontal arm 15 cm. long which carries at its outer end and at right angles to it a disc 22.3 mm. in diameter. The size and position of the disc, the circle, and the opening *O* and their distances from each other sustain such relations that when the eye is in position 25 cm. in front of the opening *O*, the line of regard contains the centers of the opening *O*, of the circle, and of the disc; and the inner edge of the circle is just contained within the stimulus-opening; and the edge of the disc is just contained within the circle. That is, in effect the device is a peep-sight arrangement, and the alignment described above is possible only when the eye is in such a position that the line of regard is perpendicular to the stimulus-opening, the circle, and the disc at their centers. The device is attached to the metal frame by means of a screw with a milled head, so that after the alignment is made it can be readily turned out of the road and clamped. In order that the distance of the eye may be accurately adjusted at the same time its alignment is made with the stimulus-opening, a measuring device is also provided. This device consists of a slender brass rod 25 cm. long fitted at either end with two short right-angled arms 5 mm. in length. On the end of one of these arms is a ring which is just larger than the stimulus-opening, and on the other is a brass disc of the same diameter as the ring, provided at its center with a large pupillary aperture. In adjusting the distance of the eye this disc is rested lightly against the forward surface of the eyeball and the ring against the screen *S* concentric to the stimulus-opening. When the position of the eye is once determined, a mouthboard is adjusted and clamped in position so that the observer's teeth fit into impressions previously made and hardened in wax. This fixes the relation of the observer's eye to the stimulus-opening *O*. All that is needed, therefore, at subsequent sittings to bring the eye again into this relation, is to fit the teeth into the impressions on the mouthboard. As stated above, the photometer bar when adjusted stands in a plane normal to the screen *S* and midway between

the stimulus-opening and the fixation-point. This guarantees that the stimulus-opening and the measuring-disc at the fixation-point shall receive equal amounts of light from the lamp on the bar. The nearer end of the bar is placed at a distance below the level of the center of the stimulus-opening and fixation-point equal to the height of the center of the filament of the lamp above the bar. Owing to the fact that the head may cast a shadow on the stimulus-opening when the bar is horizontal, the rear end of the bar is raised until the stimulus-opening and the screen for some distance around are free from shadow for any position of the lamp on the bar that may be needed to obtain the photometric balance. In order to provide for this tilting, the bar is made adjustable in height. It is supported on two heavy tripod bases each carrying a vertical stem made of hollow tubing split at the upper end and provided with collar and set screw. Into these tubes fit rods attached to the photometer bar by means of hinge joints. This arrangement permits of an independent adjustment of the height of the two ends of the bar. In order that a given amount of slant may be reproduced at any subsequent observation, an attachment is provided to indicate the angle which the bar makes with the vertical. This consists of a graduated half circle attached just above the hinge joint to the supporting rod furthest from the screen. On this rod just below the hinge joint is fastened a pointer. When the further end of the rod is raised this half circle is rotated past the pointer and the amount of rotation may be directly read from its graduated limb. Since the angle at which the bar is tilted is kept the same for the comparison and standard lights, the tilting interferes in no way with the accuracy of the photometric balance or the application of the law of squares to the determination of the relative luminosities of the standard and comparison lights.[1]

[1] We hope soon to use the principle upon which the method is based in connection with apparatus which will be more conveniently applicable to the general needs of the photometrist than is the rough device which is described above. One of the improvements which we expect to make, for example, is to eliminate the need of a slanting bar. For while the slanting bar does not interfere with the establishment of a correct photometric balance at the screen, it is not the most favorable condition under

The method is applied as follows: The observer's eye is lined up with the stimulus-opening in the manner described above and the contrast stimulus is put in position. The standard lamp is placed on the photometer bar at a given distance from the screen, the eye is turned out to the fixation-point and the sectors on the measuring disc situated just back of the fixation-point are adjusted by means of a number of separate judgments to match the gray at the stimulus-opening darkened by contrast.[1] The relative value of these sectors becomes the index of the illumination of the screen for the standard lamp at the given distance. The standard lamp is then removed, the comparison lamp is placed on the bar, and its position is adjusted

which to operate all types of lamps. This should not be difficult to do by moving the observer farther from the screen and using a correspondingly larger stimulus-opening and a greater linear distance from this opening to the fixation-point.

[1] That is, with the change in the amount of light falling on the photometer head made up of gray stimulus and surrounding screen of white, there is a change in the amount by which the gray stimulus is darkened by contrast from the surrounding screen. This amount is recorded on the measuring disc directly behind the fixation-point, by adding a sector of black to the gray sector, which was chosen, it will be remembered, of the brightness of the gray stimulus uninfluenced by contrast. The value of this black sector thus becomes the fixed index of the amount of light falling on the screen in any given case. In short, with a given brightness relation of contrast stimulus to surrounding screen, there is a finely graduated scale of contrast values inversely correlative with the amounts of light falling on the screen. That is, with a large amount of light or high illumination of the screen, the amount of contrast induced is low; with a small amount of light falling on the screen the amount of contrast induced is high. The amount of change of the illumination of the screen needed to produce a noticeable change in the amount of contrast induced is very small indeed, and because of this the method possesses a high degree of sensitivity. So far as we are able to determine, the amount of change in this illumination required to produce a just noticeable change in the contrast sensation is no greater than is needed to produce a just noticeable change in the positive sensation under the best conditions that have been as yet devised in photometric work for making the judgment, namely, the conditions presented by the Lummer-Brodhun photometer heads of the most improved type when the lights compared are the same in color quality. If this were not true, the method could not show, as it does, as great sensitivity for lights either the same or differing in color quality as does the equality of brightness method for lights of the same color quality. Also so far as we have been able to determine there is no greater variability in the eye's sensitivity to contrast from day to day than there is in its sensitivity to brightness itself. That is, photometric determinations by this method of a given light density on the screen show a very small mean variation from day to day, quite comparable in fact, with the mean variation found in judgments of brightness equality, when there is no difference in color quality to confuse the judgment. There is, moreover, so far as we have applied the method, a comparatively small variation for different observers.

until the contrast-stimulus again just matches the measuring disc. Since the proportion of sectors has not been changed from that which was determined for the standard lamp, it can be assumed that the illumination of the contrast screen is again of the same value it was for the standard lamp at the given distance. The comparative luminosities of the two light

TABLE I

SHOWING A COMPARISON OF THE RESULTS OBTAINED BY THE CONTRAST AND EQUALITY OF BRIGHTNESS METHODS

Source of Colored Light[1]	Color	Distance of White Light Giving Equality of Illumination		Sensitivity or Amount of Change that Can be Detected by				Precision or the Mean Deviation from the Average			
		Equality of Brightness Method	New Method	Equality of Brightness Method		New Method		Equality of Brightness Method		New Method	
		Cm.	Cm.	Cm.	Percentage (Candle-power)	Cm.	Percentage (Candle-power)	Cm.	Percentage (Candle-power)	Cm.	Percentage (Candle-power)
87 cp. 41 cm. distant from photometric screen	Red	66.1	66.6	2.0	5.6	0.5	1.3	1.1	3.2	0.20	0.55
	Blue-green	59.5	59.5	2.5	7.85	0.5	1.65	1.5	4.85	0.22	0.97
52 cp. 38 cm. distant from photometric screen	Red	82.2	82.2	2.1	5.0	0.5	1.1	1.1	2.5	0.20	0.41
	Blue-green	70.9	70.5	4.0	10.4	0.5	1.4	2.0	5.5	0.25	1.1
13 cp. 38 cm. distant from photometric screen	Red	160.6	160	3.0	3.7	0.5	0.65	1.6	1.9	0.23	0.3
	Blue-green	134.5	134.9	4.0	5.7	0.5	0.76	2.2	3.2	0.24	0.46

sources, thus, can be computed directly by the law of squares from distance readings on the photometer bar. The advantage of the method for color photometry is, as has already been pointed out, that in the judgment in case of both the standard and comparison lights, the surfaces, the brightness values of which are being compared, are both illuminated by the same light. The eye is thus never compelled to make its judgment of two surfaces differing in color quality. The method is in fact almost if not quite as sensitive for the

[1] The colored lights were obtained in these experiments by means of the Wratten and Wainwright filters inserted in openings in the front of lamp-houses. The red filter used transmits the spectrum from .768 μ to .65 μ; and the blue-green from .52 μ to .465 μ.

photometry of lights differing in color quality as it is for the photometry of lights of the same color quality or for colorless light; and its sensitivity for lights of the same color quality or for colorless light compares very favorably, by test, for the same observer with photometers of the best Lummer-Brodhun type. The indirect vision judgment, it may be said, however, presents more difficulty to the unpractised observer than is afforded by the flicker judgment, but this difficulty yields rather readily to practice. The method has been in almost daily use in our laboratory for four years. It has, for example, been employed exclusively for the standardization of the illumination of our optics-room in the determination of color sensitivity.

Table I. has been prepared to show a sample of a comparison of the results of this method and the equality of brightness method. These results are typical. They report the average of twenty-five determinations. Sensitivity and the average deviation or precision are expressed both in divisions of the photometer bar and in percentage candle-power. The lamps used for this work were standardized by the New York Electrical Testing Laboratories. They were operated on a storage battery circuit.

With some modifications the contrast principle described above can be used for the determination in terms of pigment standards of the white-black value of colored papers for a given degree of illumination of the papers. The method of doing this can perhaps best be explained by comparing it with the method just described. In this method, it will be remembered, we determined how much contrast would be induced by one surface upon another of a lower coefficient of reflection when a given amount of light was incident upon the two surfaces, and used this amount of contrast as an index of the amount of light falling upon the two surfaces in establishing the photometric balance, or equality of illumination at the screen. Here the relation of coefficient of reflection of the screen to the stimulus is fixed and the amount of light falling on the screen from the comparison lamp is varied until the right amount is obtained to give the photometric balance with the

standard lamp. In the determination of the white-black value of a colored paper under a given illumination, the situation is a little different. The amount of light falling on the screen is kept constant and the relation to the screen of the pigment standard which is to express the white-black value of the color, must be varied until the right one is obtained. Here again we find out how much contrast is induced by one surface upon another of a lower reflection coefficient, in this case the colored paper; and this amount of contrast is taken as an index of the brightness relation of the colored paper to the surface of higher reflecting power, the screen *S* in Fig. 1, for the given intensity of illumination. The problem thus becomes to determine what gray sustains the same brightness relation to the screen *S* as does the colored paper. This gray should represent the white-black value of the color.

In detail the method is as follows: The stimulus-opening *O* is filled with the colored paper for which the determination is to be made and a disc of the same color is made a part of the measuring disc. The fixation is taken and black is added to the color on the measuring disc until it is sufficiently reduced in brightness to match the stimulus color darkened by contrast. The amount of black that has to be added becomes the index of the amount of contrast induced and therefore of the brightness difference between the screen *S* and the colored paper for the degree of illumination used, and is kept constant during the remainder of the work. In order to be able to find out what gray differs as much in brightness from the screen as does the colored paper, a disc made up of variable proportions of white and black is substituted for the colored stimulus behind the screen; and a sector made up of variable proportions of the same white and black, for the colored sector on the measuring disc. The white and black are then varied in proportions which are carefully kept equal for stimulus and sector until a match is obtained. When this match is gotten the relative amounts of white and black either in the stimulus disc or the substitute sector on the measuring disc should give the gray value of the color for the illumination employed. That is, there is obviously only one

gray that could be used in place of the contrast stimulus and in the substitute sector in the measuring disc which would satisfy the conditions of the experiment, and that is a gray having the luminosity or white-black value of the color originally used. It is scarcely necessary to caution that throughout the determination the light falling on the screen, the stimulus and the measuring disc must be kept constant. Care must be taken also in this case not to take the fixation so far from the stimulus-opening that a color difference is present between stimulus and measuring disc.

If the determinations are wanted in photometric units they can be gotten by the equality of brightness method from the grays which have been equated with the colors. A convenient instrument to use for this purpose is the Sharp-Millar portable photometer with its scale calibrated to give results in terms of candle-power per sq. in. The calibration can be readily made by the experimenter from a magnesium oxide surface with a known amount of light falling on it. If the light incident on the grays is daylight, the same difficulty will be experienced with the Sharp-Millar photometer, however, which was mentioned earlier in the paper, namely, the two halves of the photometer field will differ in color quality due to the fact that the carbon standard in this instrument gives a light rich in the long wave-lengths.

[1] In discussing the application of this method to the determination of the brightness of colored papers, reference should probably be given to the discussion of the Talbot-Plateau law in the paper preceding this. (See Ferree and Rand, 'A Preliminary Discussion of the Deficiencies of the Method of Flicker for the Photometry of Lights of Different Color,' *Psychol. Rev.*, 1915, 22, pp. 149–150.)

A PRELIMINARY STUDY OF TONAL VOLUME[1]

BY G. J. RICH, A.M.

It is a matter of common observation that high tones are, in general, small, sharp or pointed, while low tones are large, massive or voluminous. This fact is generally admitted by psychologists, though some, like Sully,[2] doubt whether the ear can distinguish 'degree of extensive magnitude.' But when we turn to the systematic treatment of tonal volume, we find marked disagreement. According to one view, it is merely a matter of association; low tones are associated to large instruments and to gross movements of the throat. This is the position of Stumpf[3] in his early writings. Ebbinghaus[4] and Wundt,[5] while they do not ascribe the extensiveness of tones to association, still regard it as only a metaphorical characterization of the sensations, and not as an attribute. Another view is that volume or extensity is an attribute of tonal sensations, distinct from pitch. This is the view held by Titchener,[6] Stumpf[7] (in his later works), James,[8] and Calkins.[9] Dunlap[10] admits an extensive attribute, but identifies it with pitch. Lehmann[11]

[1] From the psychological laboratory of Cornell University.

[2] J. Sully, 'Outlines of Psychology,' 1889, 129.

[3] C. Stumpf, 'Ueber den psychologischen Ursprung der Raumvorstellung,' 1873, 298 ff. 'Tonpsychologie,' I, 1883, 207 ff.

[4] H. Ebbinghaus, 'Grundzüge d. Psy.,' I, 1902, 277 f., 423 f.; 1905, 294 f., 445 f.; 1911, 296 f., 458.

[5] W. Wundt, 'Physiol. Psy.,' II, 1910, 78.

[6] E. B. Titchener, 'Feeling and Attention,' 1908, 13 ff. 'A Text Book of Psychology,' 1911, 94 f.

[7] C. Stumpf, 'Tonpsychologie,' II., 1890, 56 ff., 535 ff. Ber. d. 6 Kongr. f. exper. Psychol., 1914, 300.

[8] W. James, *Mind*, XII., 1877, 1.

[9] M. W. Calkins, 'An Introduction to Psychology,' 1905, 54, 93. 'A First Book in Psychology,' 1912, 43.

[10] K. Dunlap, 'Extensity and Pitch,' *Psych. Rev.*, XII., 1905, 287 ff. 'A System of Psychology,' 1912, 215.

[11] A. Lehman, 'Folia Neuro-biologica,' IV., 1910, 119 f.

and Waetzmann[1] believe not only that extensity is intrinsic to tones, but also that it has a physiological equivalent in the area of the basilar membrane set in vibration by tonal stimuli.

The work here reported attempts to put the question to the test of experiment. The means used was the determination of the differential limen for judgments of volume at different points of the tonal scale. If volume is an attribute of tone, we may expect the judgments to be made with comparative ease and to be fairly consistent. If, on the other hand, it is due to association, we may expect large variations in the judgments. If pitch and volume are separate attributes we may expect, by the criterion of independent variability, that they have different limens, and that the course of the limens will be different. If they are two names of one and the same attribute, as Dunlap asserts, they will have the same limen.

Observers, Apparatus and Method.—The observers in the experiment were Mr. H. G. Bishop (B.), assistant in the department of psychology; Mr. F. L. Dimmick (D.), graduate student in psychology; and Mr. W. Feller (F.), undergraduate with no previous experience. B. and D. had had several years of training in psychological observation and in music; F. was entirely untrained in observation and was also unmusical. All of the observers knew in general what the problem was; they knew, that is, that it bore upon the determination of difference limens for volume; and B. and D. knew something of the theories of volume. F. was employed only in the preliminary part of the work.

The instruments used were four Stern variators and a piston whistle. They were blown from a compressed-air system which was kept at a pressure of 10.5 mm. of mercury. This pressure, which was of course too high for the apparatus, was reduced by a system of valves. It was practically constant during the experiment. The lowest variator (100–150 vs.) was blown at a pressure of 1.5 cm. of water (read while blowing); the next (150–300), at 2.2 cm.; the third

[1] E. Waetzmann, 'Folia Neuro-biologica,' VI., 1912, 24 ff.

(300–600), at 3.3 cm.; the fourth (650–1,200), at 5.7 cm.; and the whistle at a pressure of 27.9 cm. of water. The whistle is fitted with micrometer adjustment of pipe-length, but not of mouth-width; this was, however, kept constant during the experiment. It gives tones above 1,000 vs. The variators were tuned by comparison with standard tuning forks; they were set accurately within one vibration. The whistle was calibrated by means of Marbe's *Sprach-melodie-apparat.* Both variators and whistle were standardized for 20° C. During the experimental work the room-temperature never deviated more than 4° from this value; the maximal temperature-error was therefore 0.8 per cent.

In the final series, the limens were found for standard tones of 110, 200, 400, 800, and 1,600 vs. by the method of constant stimuli. Series of seven comparison-stimuli were used, the differences being for the various standards 3, 5, 8, 15, and 35 respectively. Fifty series were taken with every standard, twenty-five in each time order. The order of the comparison-stimuli within the series was determined by chance; but it, as well as the order of the two time-relations, was kept the same for all standards. In giving the stimuli, E was guided by a pendulum beating forty single swings in the minute. He gave two 'ready' signals, one swing apart, and the first tone one swing (1.5 sec.) later. The second tone followed after two swings (3.0 sec.). The duration of each tone was approximately one half-swing of the pendulum.

The observers were instructed to give judgments of the 'size' or 'volume' of the two tones, irrespective of pitch or intensity. They were to judge the second tone in terms of the first, as larger (greater), same (equal), or smaller (less). They were not further instructed as regards a criterion of volume. They sat with back turned to the apparatus, and three to four feet distant from it. D. sat just inside a dark-room, as he reported that he could observe more easily in the dark.

Fifteen series were taken in an hour's work, five at each one of three standards. The order in which the various standards were used was so chosen that the number of series

for all standards was approximately the same. The effect of practice was therefore sensibly the same for all five limens. No introspection was required during the series, but at the end of every hour's work the observers were asked for total introspections, and especially concerning their criteria of judgment.

At the very beginning of the experiment, a few practice-series were run through. B. and D. were able to judge volume immediately, and required only a single hour of practice; F. required some four hours before he could give consistent judgments. At first, he tended to confuse volume with intensity.

A preliminary determination was made of the upper limens at 100, 200, 400, and 800 vs. Fifty series were taken in every case; but the precautions regarding standardization of apparatus, etc., taken for the later work were not here observed. The results are given only for comparison. They are especially subject to errors due to unequal practice. Two sets of introspective series were also taken during this preliminary work. In addition, a very rough determination was made of the pitch limen. This merely served to show that the observers were not judging pitch; the limens were everywhere much smaller for pitch than for volume. Otherwise, the results are too rough to be of value.

TABLE I

PRELIMINARY RESULTS

Standard	Obs. B			Obs. D			Obs. F		
	D. L.	h	Rel. D. L.	D. L.	h	Rel. D. L.	D. L.	h	Rel. D. L.
100	7.711	.3130	.0771	6.279	.2371	.0628	3.501	.2216	.0350
200	11.705	.2203	.0585	8.012	.2421	.0401	5.765	.2027	.0283
400	18.040	.1080	.0451	12.770	.1156	.0319	9.084	.1316	.0227
800	41.163	.0730	.0514	28.583	.0676	.0356	23.288	.0887	.0292

The limens for volume were all computed from the raw data by the $\phi(\gamma)$ hypothesis. Urban's tables were used, and the numerical work was checked. In working up the crude results all judgments of 'doubtful' were considered as equal cases.

Results.—The numerical results are shown in the accompanying tables. Table I. gives the results of the preliminary series. Under each observer, the first column gives the computed limen (all upper limens); the second column the measure of precision, h, for the determination; and the third column the relative difference limen, obtained by dividing the difference limen proper by the standard stimulus.

Table II. gives the results of the main experiment. The

TABLE II.

UPPER AND LOWER LIMENS AND INTERVALS OF UNCERTAINTY

Standard	Limen	Obs. B			Obs. D		
		D. L.	h	Inter. of Uncertainty	D. L.	h	Inter. of Uncertainty
110	Lower	4.500	.2272	8.667	8.574	.1349	14.072
	Upper	4.167	.3530		5.498	.2344	
200	Lower	8.458	.4199	17.422	11.109	.1635	21.027
	Upper	8.964	.2197		9.918	.1645	
400	Lower	12.187	.2171	26.187	12.661	.0891	27.542
	Upper	14.000	.2065		14.881	.1300	
800	Lower	23.551	.0689	50.252	24.799	.0637	48.541
	Upper	26.701	.0928		23.742	.0752	
1,600	Lower	64.340	.0415	122.980	62.760	.0274	117.050
	Upper	58.640	.0373		54.290	.0366	
6,400[1]	Lower	229.950	.0065	502.800	149.010	.0059	360.440
	Upper	272.850	.0056		211.430	.0050	

upper and lower limens are computed separately, and are given with their measures of precision. The intervals of uncertainty are also given.

In Table III. the means of the upper and lower limens

TABLE III

MEAN DIFFERENCE LIMENS

Standards	Obs. B		Obs. D	
	D. L.	Rel. D. L.	D. L.	Rel. D. L.
110.....	4.333	.0394	7.036	.0637
200.....	8.213	.0411	10.513	.0526
400.....	13.093	.0327	13.776	.0344
800.....	25.126	.0314	24.270	.0304
1,600.....	61.490	.0384	58.520	.0366
6,400[2].....	251.400	.0393	180.220	.0282

[1] These limens were determined after the main work had been completed. They are thus not comparable (on account of increase of practice) with the other values of the table. The stimuli were given by an Edelmann-Galton whistle, calibrated by Kundt's method; the comparison-stimuli differed by 100 vs.

[2] See preceding footnote.

are given. The relative difference limens calculated from these means are also given.

Turning now to the introspective results, we present sample introspections to show the criteria used by the different observers, and the changes which these criteria underwent. At the beginning of the work, B.'s main reliance was upon imitative kinæsthesis. On the second day he says: "My criterion of difference is largely kinæsthesis. I do not judge much by vision. Difference is in mouth kinæsthesis; volume equal if I can sing the two tones without modifying mouth kinæsthesis. Also body kinæsthesis. Sometimes small tones seem as if body were contracted, pulled up tight. When there is less of this, it is a larger tone." A little later, in an introspective series: "The first tone was localized in tongue and mouth, with merest trace of kinæsthesis in throat. It was spread vaguely throughout the mouth and not localized certainly. The second tone was felt as localized in all of the chest muscles. The whole chest felt big and roomy." Still later: "I do not think criterion is uniform. I do not always judge by the same standard, but I do judge the same thing. . . . When I am not able to avoid pitch, it too is judged in kinæsthetic terms; so that the whole thing really becomes a judgment of kinæsthesis against kinæsthesis. . . . I am not sure that all judgments are of the kinæsthetic sort. Many of them are more vague, so vague that I don't know much about them. These are the ones, apparently, that are used when there is no trouble to distinguish between pitch and volume." Here he begins to drop secondary criteria. He never gets completely rid of them, and descriptions of localization in mouth, throat, etc., run all through his reports. But he is of a predominantly kinæsthetic type, and judges pitch in the same way. This is shown in the last report quoted, and again a little later: "I don't know whether the difference is inherent in the sounds themselves or not. I know perfectly well what volume is, and it is immediate with the tone. I can't hear a tone without having a setting for it. I have this for both pitch and volume." In the last introspective series, just before the last quantitative work, he

finds a number of cases where the judgment comes immediately, without secondary criteria, though the kinæsthetic judgments are still the most frequent. In the final series, he begins to talk of kinæsthetic set. "The criterion most of the time is a particular kinæsthetic set. I am not sure whether it is there all of the time. I don't think I ever judge volume without having some kinæsthesis; the amount of it varies. Sometimes I seem to take the thing almost visually in terms of eye-rotation. I think this kinæsthesis is only image, though I am not sure." "By repeated practice the kinæsthesis I had isn't so elaborate. A little tag of it seems to carry the judgment. Sometimes I judge automatically."

D. relies less upon secondary criteria. At first he says: "I try to judge by the bigness of the thing, the roominess. . . . The larger tones seem to have a greater diffuseness. It seems as if the smaller ones fill space more compactly, what they fill." Visual imagery comes in very often. In an introspective series he says: "I visualized the last one as larger. . . . I think of them as bands of grays, both about the same width, the smaller one shorter than the other. . . . There is also a kinæsthetic component. I seem to repeat the sounds over again in my throat. . . . Also, I have a tendency to want to spread out my hands to demonstrate the size of the larger." Later on the secondary criteria tend to drop out, and the judgment becomes more direct. "There is a difference in size there. It is awfully hard to describe. I do not think it is a *meaning* applied to the thing. It isn't anything you read into the tone. I mean by that, that I don't get this idea of size from anything else, any imagery, any muscular movement. The size of the tone seems to be a part of the tone itself, just as much as the pitch is. I don't think I am judging pitch. I am not sure what my criteria are. In fact, I feel that I am judging a quality of the tone itself. I hear the difference in volume, just as I hear the difference in pitch." Again: "I think this is an actual difference in size. That is the thing that strikes me most definitely. It is actually larger. It is a different kind of size from visual size. . . . Space is so visual to me that,

when I open my eyes, it seems a sort of folly to me; but when I close my eyes I feel the massiveness of the tones." Towards the end of the work, D. tends to report almost entirely in terms of attribute. "I was judging independently of pitch, although I can't help but notice the pitch. I think of the tone in this analytic way when I am trying to get at the volume." "The volume seems to be something different from the pitch. The large tones are roomier, bigger." Towards the end: "If I were to analyze the tone I should give it the three qualities of pitch, vowel, and volume. The volume is the hardest to judge, but I think I am doing it without at all mixing it with the other two. The difference between the volume of two tones is not the same, qualitatively, as between the pitch; that is, tones that are alike in pitch are practically identical, but, for volume, they seem to fall into groups, within which there is considerable variation in pitch and some in vowel quality. In judging, I try to group them in proper groups. I do have some kinæsthesis of the throat, but I cannot say that it plays any part in the judgment."

F. talks more of the meaning of volume than of his actual criteria. At first he says: "The biggest tones seem to fill me up more, to come from a bigger vessel." "Difference of volume is bigness of sound. It seems to take up more space, to fill me up more. It is an effect similar to an odor in filling the lungs." "Volume is the bigness of the vessel the tone comes out of; the way I hear it, whether it seems to go through me, to have a filling effect; the capacity of the sound." Later: "I am so used to some of the sounds now that they don't appeal to me as they used, in respect to volume. They don't have the filling effect on me that they had. Now I use as criterion the size of the vessel emitting the sound, and I seem to imagine the sound visually, as spread out behind me." "I noticed on several occasions that the volume of the sound appeared to be distinct from the pitch. I noticed both, but I could imagine the pitch as being emitted by the instrument, and the volume appearing like an enveloping atmosphere or medium. While the pitches were different,

the mantle of sound around them seemed to be of the same bigness. In most cases I can't seem to help noticing the pitch. I try not to use it as a criterion for volume judgments, but cannot say whether I do or not."

Our observers are evidently not judging pitch. For one thing, they are able to distinguish introspectively between pitch and volume. Moreover, the limen for pitch is in every case much lower than that for volume. F. admits, it is true, that he sometimes uses pitch as a guide for judgments of volume; and his volume-limen is, in fact, lower than that of the other observers. But even so he is judging something more than pitch. For the other observers there is no doubt.

We may next inquire whether the observers were giving judgments of an attribute of the tone itself, or of something associated to the tone. D. is positive that volume is as much a part of the tone as is pitch. What secondary criteria he had came in only incidentally, and were not essential to the judgment. B. has more secondary criteria; and it might be thought that he is judging in terms of associated kinæsthetic images. But then he judges pitch in these same terms, and pitch is undeniably an attribute. Besides, with practice his judgments of volume become more automatic. F.'s reports are almost wholly in terms of meaning; and it is difficult to say what, psychologically, he was observing. He observed, as we have said, only for a short time.

The numerical results show a high degree of consistency. In the preliminary work, B. had everywhere the highest limen, D. the next highest, and F. the lowest. In the main series, D.'s limens are practically unchanged, though they are slightly higher than before in three cases. But B.'s values are much lower than in the preliminary series, and come very close to those of D. The change is evidently due to practice. The discrepancy between the final figures for B. and D. at 110 and 200 is probably due to imperfection of the apparatus; D. found these low tones weak, noisy, and hard to judge. In particular, D.'s lower limen at 110, which is entirely disproportionate to the upper limen, must probably be referred to this imperfection of the apparatus.

The value of the relative difference limen is fairly constant for the whole range. In the results for B. and F., it is as nearly constant as the ordinary limen for intensity under Weber's law. The figures for D. show the same trend, save where the results are vitiated by the observer's difficulty with the lower variators. This course is entirely different from that of the limen of pitch.[1] If, then, we accept independent variability as the criterion of an attribute, we have a strong case, so far as the present work goes, for the differentiation of pitch and tonal extensity.

Conclusions.—(1) Judgments of tonal volume can be made with ease, and with as great consistency as is usual for attributive judgments.

(2) The judgments may be made on an attributive basis. After secondary criteria have been eliminated, by practice, they are as immediate as judgments of pitch.

(3) Within the limits of our experiment, the relative difference limen of tonal volume is approximately constant.

(4) This limen is different from that of pitch, both in magnitude and in course.

[1] See collected results in Titchener, 'Experimental Psychology,' Vol. 2, Part 2, 237 f.

OUTLINE AS A CONDITION OF ATTENTION

BY HERBERT WOODROW

University of Minnesota

Observations have recently been made in the psychological laboratory of Cornell University, concerning the effect of form, or outline, upon clearness. It was found by Meads[1] that a definitely outlined light, in the form of a cross, had a greater power to attract attention than a light, of the same objective intensity, which appeared merely as a "spot" that faded off gradually into its black background. It was found, further, that the light in the form of a cross could be considerably lessened in intensity and still attract as high a degree of attention as the formless spot. As a criterion of the ability of the stimulus to attract attention, introspective judgments of clearness were used; so that the statement, that the cross attracted more attention than the spot, is to be taken as meaning that the subjects judged it to be clearer. Meads's work, then, may be regarded as experimentally establishing the fact that definiteness of outline is a condition of attention, in the sense that a visual stimulus with definite outline is judged clearer than one without it.

The present study, though dealing with the same problem as that worked on by Meads, was made by a purely objective method of measuring degree of attention, one that does not require introspections of clearness on the part of the subject. I have recently described this method in detail, and given, as it seems to me, an elaborate demonstration of its validity.[2] This method seems of sufficient importance to justify testing it in every possible way, and adapting it to as many types of

[1] 'Form *vs.* Intensity as a Determinant of Attention, Minor Studies from the Psychological Laboratory of Cornell University,' communicated by E. B. Titchener and H. P. Weld, *Amer. J. of Psychol.*, 1915, 150–151.

[2] 'The Measurement of Attention,' *Psychol. Monog.*, 1914, Vol. XVII., **5**, pp. 158.

problems as possible. The problem of the effect of outline is not only an interesting one in itself, but seemed better than any other for determining the degree of correspondence between clearness as judged introspectively and degree of attention as measured objectively. On the whole, the results obtained by Meads, though reported as a minor contribution, probably form the best introspective basis at hand for testing the validity of any objective method of measuring degree of attention; and it was on this account that I undertook the present investigation. My object was not so much to study the effect of outline upon degree of attention as to ascertain whether the objective method, to which I have referred, can be given a further, introspective, justification, by determining whether it leads to the same conclusions as are reached by means of introspection on the part of trained observers. Pillsbury writes that ". . . the only test of a method is its accomplishment. . . . Any method that gives results must be kept."[1] It will be seen from the data below, that both the objective measurements here presented and the systematic introspections reported by Meads result in the same conclusion, namely, that definiteness of outline is a condition of attention.

The objective method used is one employing reaction times. It consists in first obtaining a series of reaction times with a regularly repeated preparatory interval of 2 secs., and then in obtaining a series of reaction times with a set of irregular preparatory intervals of widely differing lengths. The reciprocal of the absolute prolongation produced by the irregular preparatory intervals is taken as the measure of the degree of attention given to the stimulus, or rather to the change of stimulus, to which the subject reacts. The theory of the method is similar to that of the well-known distraction methods that have been proposed for the measurement of attention. The unfavorable preparatory intervals are regarded somewhat as a distracting influence, though in view of the fact that they merely constitute an obstacle to a high

[1] 'The Function and Test of Definition and Method in Psychology,' *Science*, Vol. XLI., 1915, 1054, 375.

degree of attention, without causing a division or tearing apart of attention, it seems preferable to speak of them as a *detracting* influence. The absolute prolongation in reaction time which is produced by the use of the irregular preparatory intervals may be spoken of as the absolute detraction effect. I have previously shown that this absolute detraction effect varies inversely as the degree of attention given to the change in stimulus to which the reaction occurs.[1] The reciprocal of the absolute detraction effect may therefore be taken as a measure of the degree of attention.

Now a reaction is always a reaction to a change, and the attention measured by the method just described is, therefore, always the attention to some change. Hence, to study outline as a condition of attention, it is necessary to determine whether a variation in the definiteness of outline of a stimulus causes a variation in the degree of attention to some change in that stimulus. If the degree of attention becomes greater as the stimulus becomes more definite in outline, we may expect that, at the same time, the degree of attention to a given change in the stimulus will likewise become greater.[2] The change used, in most of the work, and in all that reported in Tables I. to IV., was a slight decrease in intensity.

My procedure for studying the effect of definiteness of outline as a condition of attention, then, was as follows: Two visual stimuli were used, both of the same objective intensity. One was a definitely outlined square of light, the other, a formless spot. With each of these stimuli, reaction times to a slight decrease in intensity were obtained, both with regularly repeated 2 sec. preparatory intervals and with a set of preparatory intervals varying from 4 to 20 secs. and mixed in irregular order. The reciprocal of the absolute prolongation in reaction time produced by the irregular preparatory intervals is taken as a measure of the degree of attention to the decrease in intensity. If the degree of attention thus found is greater with the definitely outlined

[1] *Op. cit.*, Chap. III.

[2] See Wirth, *Philos. Stud.*, Vol. XX., 1902, 625–635. Also Woodrow, *op. cit.*, 118.

square than with the spot, it means that definiteness of outline is a condition of attention.

The intensity of the stimulus used was quite weak, since it was found that the difference in clearness between the spot and square was then much more pronounced than when the intensity was great. The change in intensity, it is important to note, was produced at the source of illumination, a stereopticon lamp, and therefore affected the entire square and the entire spot. As some of the subjects could notice a much smaller change in intensity than others, different sized decreases were used with different subjects. In each case, preliminary trials were made to determine the size of decrease just great enough to be always promptly noticed, even in the case of the spot, with irregular preparatory intervals. When the size of decrease suitable for a given subject was once determined, it was not thereafter changed. It was found that as the size of the change in intensity was increased, the effect of outline became less important. However, even with the subjects who had the finest discrimination, subjects Ll and Ww, the largest size of change used, that with subject Bn, was still affected by outline.

Before deciding to use a decrease in intensity as the change in stimulus to which the subject should react, I made preliminary trials, with several of the subjects, in which I used a slight increase, and also the complete cessation and the simple occurrence of the light. With some subjects, provided a light of weak intensity was used, the degree of attention to any of the four types of change was markedly affected by definiteness of outline. However, in the case of the mere occurrence or the complete cessation of the stimulus, or even with a very large increase or decrease in intensity, unless the stimulus was very weak, the effect of outline upon the clearness of the change was comparatively slight. This was determined not only by introspection but by a number of measurements of the degree of attention. When the mere occurrence of the light was used as the reaction stimulus, even with a weak light, one of the two subjects tried showed absolutely no effect as the result of outline, while the other

showed a marked effect. The subject who showed no effect gave the introspection that he reacted before he became definitely aware of the outline, he merely knew that "something had happened out there, and apprehended it as a definite square or as a spot only after reacting." This introspection would suggest that an awareness of the form of the outline is first necessary if it is to exert a favorable influence on the degree of attention. Further investigation, however, with very weak intensities of stimulus, and with more subjects, would be necessary to establish this point.

The subjects were carefully instructed to make every reaction as quick as possible. Only with such instructions is there any guarantee of the soundness of the method used, for then, only, is the time required for the reaction an adequate measure of the subject's efficiency. As the stimuli were always in view, no special fixation point was provided. The subjects merely fixated as nearly as possible the center of the stimulus, whether square or spot.

In all, seven subjects were used. With two of these, a series of 10 measurements were made, for both square and spot. With the others, as many measurements were made as their time permitted. At each sitting, 50 reactions were taken with both the square and the spot, 25 with a regularly repeated interval of 2 secs., and 25 with irregular preparatory intervals. The order in which the square and spot were used was changed each day. The set of 25 irregular preparatory intervals was the same as I have used in previous work, namely, 4, 16, 20, 4, 8, 20, 12, 16, 8, 4, 12, 4, 20, 8, 12, 4, 16, 20, 8, 16, 12, 12, 8, 16 and 20 secs. The order of the first few intervals was changed occasionally with those subjects who were used oftener than two or three times.

Details of Apparatus.—The lights used as stimuli were projected from a stereopticon onto a ground glass partition 180 cm. square, built into the wall separating the subject's room from the experimenter's room, both of which rooms were dark-rooms. The only illumination in the experimenter's room was a small shaded lamp, by which to read the chronoscope. The light from this lamp was prevented from falling onto the projection glass by a curtain, which entirely screened off the experimenter's end of the room. Between this curtain and the projection glass, was placed the stereopticon, the objective of which came about 75 cm. behind the glass. The stereopticon was illuminated by a frosted-tip, 40-watt, Mazda, tungsten lamp, in series with another

40-watt Mazda, on a 115-volt D.C. circuit. The intensity of this light was very considerably reduced by means of a yellow and a blue-green sheet of gelatine, placed in the path of the projected rays. The voltage for the lamp circuit was supplied from the university power-house. A Weston voltmeter was kept constantly connected with the circuit terminals, and placed right behind the chronoscope, where the experimenter could watch it. Most of the time the voltage was fairly steady. On certain days it was not, however, and work was given up on those days. Throughout the great majority of sittings, there was not a variation of more than 2 to 4 volts, and no sudden jumps.

In order to obtain a spot of light without definite outline, the stereopticon objective was thrown completely out of focus, and no slide put in the slide-holder. The subject's room was dimly illuminated by a 10-watt frosted Mazda placed about 5 meters behind, and 2 meters above, the subject's head. This dim illumination was used to make it easier to secure perfect retinal adaptation, as it is well known that a very long and variable time is required for complete adaptation to darkness. With this illumination of the subject's room, the spot of light appeared somewhat yellowish green, but very poorly saturated. It differed but little in color tone from the rest of the ground-glass plate which formed its background. It is difficult to give the dimensions of the spot, as it shaded off so gradually that it was impossible to tell where it ended. Its just visible edge was about 18 cm. in diameter. It was just noticeably less bright at 4 cm. from the center than at the center.

The square of light was obtained merely by lowering a dark gray paper screen on the opposite side of the projection plate from the subject. In the center of this screen was cut a square 7 x 7 cm. The change from spot to definitely outlined square was made, then, simply by cutting off the edges of the spot. The reason for using a square, instead of following Meads in the use of a cross, is that a square was found to present a surface of more uniform brightness than a cross of the same area. Along the border of the square one could discern a narrow contrast rim, 2 or 3 mm. wide, of heightened intensity. The brightness of the screen itself was so chosen that, upon being lowered into position, it did not change the apparent intensity of the background.

The decrease in brightness to which the subjects reacted was produced by closing a circuit in parallel with the stereopticon lamp. This circuit contained a series of four Mazda lamps, which were not the same for all subjects. By varying the resistance of these lamps, the amount of decrease in the intensity of the stimulus could be varied. As already stated, a decrease in intensity which seemed just sufficient to be always promptly noticed by the subject was chosen by preliminary trials with each subject.

The circuit in parallel with the stereopticon lamp was closed simultaneously with the separate chronoscope circuit, by means of a double key. The chronoscope, a Hipp's, was arranged in series with a storage battery of about 12 volts, and controlled before and after each sitting by the Wundt fall-hammer, set for a time of 201 σ. The warning signal used was the click of an electric sound-hammer. The duration of the preparatory intervals was judged by the experimenter with the aid of a head telephone receiver, connected with an electric metronome, beating seconds, in an adjoining room.

The results for each subject are given in Tables I. and II., and a summary of the results for all subjects in Table III. The reaction times obtained with the definitely outlined square are given in the columns headed 'Square,' and those with the

indefinitely outlined spot in the columns headed 'Spot.' The columns headed '2 secs.' and those headed 'Irreg.' give the average reaction times with regularly repeated 2 sec. preparatory intervals and with the set of irregular preparatory intervals. The difference in the average reaction time with the 2 sec. intervals and with the irregular intervals is given in the columns headed $1/A$ and $1/A'$. Since this difference varies inversely with the degree of attention, A stands for the degree of attention given the decrease in intensity in the case of the square, and A' for the same in the case of the spot. The figures in italics are the mean variations of the averages above them.

A study of Tables I. to III. shows that, in every case, there was a marked prolongation in reaction time produced by the irregular preparatory intervals, but that this prolongation was always greater with the spot than with the square. Now the prolongation produced by the irregular preparatory intervals varies inversely as the degree of attention. Therefore, since at every sitting this prolongation is greater with the spot than with the square, it follows that the degree of attention to the change is less in the case of the spot than in the case of the square. The difference between the two cases in the amount of prolongation produced by the irregular intervals indicates the difference in the degree of attention. This difference is given in the columns headed $1/A' - 1/A$. In Table III., I have added another column, headed $(A - A')/A$, which, upon the assumption that the measurements of degree of attention made by the present method may be regarded as absolute measurements, gives the percentage of decrease in degree of attention produced by using the spot in place of the square.

The correctness of the general conclusion that the degree of attention to the change in intensity is less when it occurs in the spot than when in the square, is strongly confirmed by the subjects' introspections. These introspections were very carefully noted throughout the work, as it was mainly the possibility of obtaining a good introspective confirmation of the method of measuring attention here used that led to the

TABLE I

THE EFFECT OF DEFINITENESS OF OUTLINE UPON DEGREE OF ATTENTION TO A SLIGHT CHANGE IN INTENSITY

Subj.	Square			Spot			$1/A' - 1/A$
	2 Secs.	Irreg.	$1/A$	2 Secs.	Irreg.	$1/A'$	
Ww	276	349	73	297	417	120	47
	33	*57*		*34*	*70*		
"	267	342	75	290	395	105	30
	42	*45*		*44*	*42*		
"	263	352	89	283	400	117	28
	32	*34*		*36*	*50*		
"	248	329	81	256	360	104	23
	18	*46*		*19*	*36*		
"	257	327	70	257	368	111	41
	19	*27*		*19*	*35*		
"	265	331	66	274	378	104	38
	18	*27*		*24*	*33*		
"	263	328	65	252	347	95	30
	29	*20*		*27*	*31*		
"	255	339	84	278	386	108	24
	38	*20*		*17*	*46*		
"	256	337	81	259	368	109	28
	32	*50*		*21*	*47*		
"	254	338	84	253	368	115	31
	30	*26*		*36*	*39*		
Av.	**260**	**337**	**77**	**271**	**379**	**108**	**31**
Av. M. V.	*31*	*35*		*28*	*43*		
Ll	282	385	103	292	436	144	41
	19	*32*		*26*	*52*		
"	268	363	95	294	429	135	40
	18	*36*		*26*	*61*		
"	274	359	85	317	479	162	77
	17	*28*		*26*	*49*		
"	286	366	80	281	394	113	33
	14	*40*		*18*	*61*		
"	272	347	75	286	422	136	61
	20	*39*		*22*	*53*		
"	278	372	94	284	446	162	68
	16	*34*		*20*	*68*		
"	277	374	97	278	431	153	56
	19	*33*		*23*	*66*		
"	276	374	98	279	422	143	45
	18	*26*		*22*	*74*		
"	275	383	108	283	424	141	33
	18	*31*		*30*	*53*		
"	274	374	100	291	429	138	38
	26	*38*		*22*	*45*		
Av.	**276**	**370**	**94**	**288**	**431**	**143**	**49**
Av. M. V.	*19*	*34*		*24*	*58*		

TABLE II

A CONTINUATION OF TABLE I

Subj.	Square			Spot			1/A'—1/A
	2 Secs.	Irreg.	1/A	2 Secs.	Irreg.	1/A'	
Fs	304	393	89	311	486	175	86
	12	*32*		*26*	*62*		
"	282	385	103	292	436	144	41
	19	*32*		*20*	*42*		
Av.	**293**	**389**	**96**	**302**	**461**	**159**	**63**
Av. M. V.	*16*	*32*		*23*	*52*		
St	280	413	133	296	479	183	50
	29	*47*		*35*	*61*		
"	295	388	93	303	441	138	45
	30	*42*		*38*	*98*		
"	297	385	88	305	427	122	34
	34	*33*		*39*	*58*		
"	288	379	91	317	465	148	59
	29	*41*		*38*	*68*		
Av.	**290**	**391**	**101**	**305**	**453**	**148**	**47**
Av. M. V.	*31*	*41*		*38*	*71*		
Bs	263	385	122	282	474	192	70
	20	*34*		*24*	*54*		
"	259	413	154	264	485	221	67
	22	*27*		*38*	*49*		
"	232	370	138	255	438	183	45
	21	*38*		*27*	*34*		
"	247	373	126	268	449	181	55
	22	*35*		*25*	*50*		
"	235	369	134	255	435	180	46
	23	*25*		*26*	*56*		
"	274	385	111	288	477	189	78
	29	*37*		*28*	*68*		
"	249	356	107	256	435	179	72
	27	*30*		*29*	*59*		
Av.	**251**	**378**	**127**	**267**	**456**	**189**	**62**
Av. M. V.	*23*	*34*		*28*	*53*		
Dg	295	426	131	322	517	195	64
	35	*59*		*36*	*48*		
"	282	407	125	299	495	196	71
	20	*43*		*28*	*60*		
Av.	**289**	**417**	**128**	**310**	**506**	**196**	**68**
Av. M. V.	*28*	*51*		*32*	*54*		
Bn	332	460	128	374	597	223	95
	33	*50*		*55*	*103*		
"	375	478	103	410	604	194	91
	36	*48*		*58*	*85*		
"	333	490	157	396	626	230	73
	28	*62*		*70*	*98*		
Av.	**347**	**476**	**129**	**393**	**609**	**216**	**87**
Av. M. V.	*32*	*53*		*61*	*95*		

TABLE III

A SUMMARY OF TABLES I AND II

Subj.	Square			Spot			$1/A'-1/A$	$\frac{A-A'}{A}$
	2 Secs.	Irreg.	$1/A$	2 Secs.	Irreg.	$1/A'$		
Ww ...	260	337	77	271	379	108	31	.28
	31	*35*		*28*	*43*			
Ll.....	276	370	94	288	431	143	49	.34
	19	*34*		*24*	*58*			
Fs	293	389	96	302	461	159	63	.39
	16	*32*		*23*	*52*			
St.....	290	391	101	305	453	148	47	.32
	31	*41*		*38*	*71*			
Bs	251	378	127	267	456	189	62	.33
	23	*34*		*28*	*53*			
Dg....	289	417	128	310	506	196	68	.35
	28	*51*		*32*	*54*			
Bn....	347	476	129	393	609	216	87	.40
	32	*53*		*61*	*95*			

present investigation. All the subjects, without exception, gave the introspection that the change was clearer and easier to notice when it occurred in the square. The subjects were all just as sure that the change in the square was clearer than the change in the spot, as they were that the square itself was clearer than the spot.

The following are a few typical introspections:

Ll: "The square stays in view better, and the effort of concentration is less. After working with the spot, I always see the square come with a sigh of relief. Always tired when through with the spot, but not after the square. Winking didn't bother in the case of the square, but was necessary with the spot to relieve strain of concentration. The change in the square is certainly clearer than that in the spot."

Bs: "The square is much clearer—easier to see. The change is easier to notice in the case of the square—no doubt about it. The change is so much more distinct in the case of the square that it gives me more of a chance to think about reacting quickly."

Bn: "Change twice as easy to notice with square as with spot."

St: "There is no doubt about it" (that the change in the square is clearer than that in the spot).

Dg: "Square is of course more distinct and somewhat

brighter, but it is also clearer, that is, makes more of an impression on you. The change is much clearer in the square."

In addition to such introspections as those noted above, systematic observations were made by myself and my assistant[1] on the effect of varying the absolute intensity of the light and also of varying the size of change in intensity of stimulus. We both observed that, with increase in the intensity of the stimulus, there occurred a marked decrease in the effect of outline upon the clearness of the stimulus, and, similarly, with increase in the size of the change in intensity, there occurred a marked decrease in the effect of outline upon the clearness of the change. The correctness of these observations was checked by objective measurements of degree of attention made with a high intensity of stimulus and a very large decrease in intensity. These measurements showed a high degree of attention to the change in intensity, in both the square and the spot, but no reliable difference between the two.

In interpreting these observations on the effect produced by variation in intensity and in size of change upon the importance of definiteness of outline, it should be remembered that just as the degree of attention to a simple stimulus is conditioned objectively by the intensity of the stimulus, so is the degree of attention to a change in intensity of stimulus conditioned by the size of the change.[2] Now, since the effect of outline becomes less marked as the size of change or the absolute intensity is increased, it is evident that the effect of outline as a condition of attention becomes less as the degree of attention affected becomes greater. For example, if the square and the spot both have a very great brightness, the degree of attention which each attracts is high, and there is then little, if any, difference in clearness between them. If, on the other hand, they are both very dim, the square is much the clearer. Similarly, as regards the effect of outline on the degree of attention to a change in

[1] Assistance in this study, as well as in several others, was made possible by aid received from the research fund of the University of Minnesota.

[2] Woodrow, *op. cit.*, 114.

intensity, if the change is large, it attracts an equally high degree of attention in both the square and the spot, but if it is small, it attracts much more attention in the square.

The fact that the effect of outline upon degree of attention becomes less important with increase in the degree of attention otherwise conditioned, is merely an illustration of the general law, that "the absolute effect of a given detractor of attention varies inversely as the degree of attention upon which the detractor acts."[1] The detractor of attention, in the present instance, is a given degree of indefiniteness of outline. Another well-known illustration of this law lies in the fact that an "attention wave" is easily discernible only in the case of a very weak stimulus, such as produced by the rotating Masson's disk, in which case the degree of clearness is also very low because of the insufficiency in the objective condition of intensity. Here we are evidently dealing with some detracting influence, of a physiological nature, which has a marked effect when the degree of attention affected is low, but little or none when it is high. I have elsewhere[2] described in detail a number of other illustrations of this law, using irregular preparatory intervals as the detracting influence.

One might ask why the simple reaction times with the regularly repeated 2 sec. intervals could not be used alone as a measure of degree of attention. Perhaps they could, in the present instance, but they would not serve as a very sensitive measure and one could not be certain that the difference in simple reaction time between the reactions to the change in the square and those to the change in the spot was due to the difference in degree of attention. The reaction process is complex, and variation in simple reaction time may be the result of variation in other factors than attention. Difference in the prolongation produced by the irregular preparatory intervals, however, can be due only to difference in the degree of attention in the two cases, since this prolongation is due solely to the effect of the set of irregular

[1] *Op. cit.*, 99.
[2] *Op. cit.*, 157.

intervals as a detractor of attention.[1] Moreover, by using the reciprocal of the absolute prolongation in reaction time produced by the irregular intervals, we obtain a measurement which is comparable with other measurements of the degree of attention, made at other times and under other circumstances.

To make an accurate comparison of the absolute effect of outline upon two different individuals, it would be necessary first to equalize their degree of attention in the case of the square. This could be done directly, by varying the size of the change to which they were to react, until the prolongation produced by unfavorable intervals was the same for both. This would consume a great deal of time, but by using several different sized changes, one could easily calculate the sizes of change needed to make the degree of attention of the two individuals the same. After having equalized the degree of attention for the two individuals to a change occurring in the square, we could then measure the degree of their attention to the same change occurring in the spot, and thus determine whether the effect of outline as a condition of attention was the same for both. No accurate measurement of individual differences has been attempted by the method just described, but there would be no great difficulty in making such. The data, as obtained, indicate marked individual differences—but it is certain that these would be greatly lessened if the subjects were made equal in degree of attention, since, in general, there is evident a considerable degree of correlation between the reciprocal of the degree of attention to the change in the square ($1/A$) and the unfavorable effect of indefiniteness of outline upon the degree of attention ($1/A' - 1/A$).

The fact, that a fixed change in the intensity of a stimulus attracts more attention when the stimulus is definitely outlined than when it is not, can be due only to the favorable effect of definiteness of outline, as such, upon the degree of attention. It is true that the square had a slightly greater average apparent intensity than the spot, presumably as the

[1] *Op. cit.*, 49–63 and 114.

result of contrast. This fact, however, would not account for the greater clearness of the change in the case of the square, for the effect of contrast is to decrease the noticeability of a slight change in intensity. Anyone may readily convince himself that this is the case, by observing a very small change in the intensity of a light when it is matched with its background in brightness, and then observing this same change when the background is either markedly lighter or darker. In the latter case, this change is less clear.[1] After all, so long as enough contrast to give a definite outline is present, variation in degree of contrast has very little effect upon the clearness of a given relative change in intensity.

In order to determine beyond question, however, whether the greater degree of attention to the square was due to any increase in apparent intensity apart from its greater clearness, an additional experiment was made. In this experiment, by using a background considerably brighter than the stimulus, the square was rendered definitely less in apparent intensity than the spot. Nevertheless, the square was definite in outline and was judged unquestionably clearer than the spot. This may seem to run counter to the statement that intensity is an important condition of attention. As a matter of fact, it merely illuminates the meaning of that statement. In the case of light, not intensity, but difference in intensity, is the real, intensive, condition of attention.[2]

An experiment was conducted, then, in just the same way as the work already described, except that the definitely outlined square was surrounded by a brighter background, and therefore rendered slightly, but unquestionably, less in apparent intensity than the spot. The definiteness of outline of the square was judged by the two subjects used in

[1] This seems to be due to the fact that the effect of contrast, relative to the difference in intensity of the contrasting surfaces, is greatest when the difference is very small. See Lehmann, 'Ueber die Anwendung der mittleren Abstufungen auf den Lichtsinn,' *Philos. Stud.*, 1886, Vol. III., 516–528.

[2] I have found by systematic introspection on the part of myself and subject Ll that the increase in clearness of the stimulus, with increase in the difference in intensity between the stimulus and its background, is marked when the difference is slight but becomes much less noticeable after a considerable difference has once been reached. This holds, no matter whether the background is lighter or darker than the stimulus.

this experiment to be about equal to that of the square with the dark background used in the work already presented. The same source of illumination and the same physical decrease in intensity were used in this experiment as in the previous work with these subjects, reported in Table I. The data are given in Table IV., where the headings of the columns have the same significance as in the preceding tables.

TABLE IV

THE EFFECT, UPON THE DEGREE OF ATTENTION TO A SLIGHT DECREASE IN INTENSITY, OF DEFINITENESS OF OUTLINE PRODUCED BY SURROUNDING THE STIMULUS WITH A BRIGHTER BACKGROUND

Subj.	Square			Spot			$1/A'-1/A$
	2 Secs.	Irreg.	$1/A$	2 Secs.	Irreg.	$1/A'$	
Ww.....	299	376	77	300	416	116	39
	38	*36*		*20*	*63*		
"	302	382	80	312	404	92	12
	32	*36*		*33*	*33*		
"	290	367	77	308	398	90	13
	29	*32*		*40*	*25*		
"	295	379	84	294	394	100	16
	26	*38*		*22*	*34*		
Av.....	**297**	**376**	**79**	**304**	**403**	**99**	**20**
Av. M. V.....	*31*	*36*		*29*	*39*		
Ll.....	297	407	110	304	484	180	70
	18	*37*		*25*	*36*		
"	301	381	80	297	426	129	49
	21	*46*		*22*	*46*		
"	263	369	106	285	420	135	29
	18	*38*		*23*	*22*		
"	265	371	106	283	397	114	8
	23	*26*		*16*	*25*		
"	306	378	72	306	415	109	35
	17	*25*		*22*	*41*		
Av.....	**286**	**381**	**95**	**295**	**428**	**133**	**38**
Av. M. V.....	*19*	*34*		*22*	*34*		

From a comparison of the values of $1/A$ in Tables I. and IV., it is evident that the degree of attention to the change in intensity in the case of the square was affected very little, if at all, by using a bright background in place of a dark one. For subject Ww, with the dark background (Table I.), the average value of $1/A$ is 77, and with the light background (Table IV.), 79; while for subject Ll, the corresponding values are 94 and 95. In the case of the spot, some improvement in the degree of attention is to be noted in

Table IV., as the value $1/A'$, for subject Ww, changes from 108 in Table I. to 99 in Table IV., while for subject Ll, its value changes from 143 to 133. Since the reactions with the spot given in Tables I. and IV. were obtained under identical conditions, the difference is due either to 'accidental variation,' or, since the results of Table IV. were obtained after those of Table I., to practice. While I have never been able to obtain any convincing evidence that the detracting effect of unfavorable preparatory intervals wears off with practice, there is no reason why practice might not lessen the effectiveness of such a detractor of attention as indefiniteness of outline.

From the data of Tables I. and IV., the conclusion follows, that the greater clearness of the change in the square is not due to the effect of contrast on the apparent intensity of the square, but to the greater *clearness* of the square, which in turn is due to the definite outline. Definiteness of outline means that there is a definite setting off of the stimulus from its background, and it is this fact alone that gives the square the greater clearness. Definiteness of outline, though it may involve brightness contrast, is thus a condition of attention apart from the effect of contrast on apparent intensity.

Conclusions

1. The effect of outline upon the degree of attention given to a visual stimulus may be measured by measuring its effect upon the degree of attention to a small change in that stimulus, preferably a small decrease in intensity. The degree of attention to any change which may be used as a reaction stimulus is measured by the reciprocal of the absolute prolongation in reaction time produced by using a set of unfavorable preparatory intervals in place of 2 sec. preparatory intervals.

2. Measurements made by this method show that definiteness of outline is a condition of attention. This statement means that the reaction time to a slight decrease in the intensity of a definitely outlined square is less affected by

unfavorable preparatory intervals than is the reaction time to the same decrease in intensity in an indefinitely outlined spot.

3. The results obtained by the purely objective method described above agree with the results of systematic introspection on the part of trained observers.

4. The effect of definiteness of outline as a condition of attention is not due to the effect of contrast on apparent brightness. The essential condition upon which the favorableness of outline depends is merely that the stimulus shall differ sharply from its background. It may be either less intense or more intense.

5. The effect of definiteness of outline upon clearness decreases with increase in the absolute difference between the intensity of the stimulus and that of its background.

6. The effect of definiteness of outline upon the clearness of a change in intensity decreases with increase in the size of the change.

Conclusions 5 and 6 are merely particular instances of the general law that the absolute detraction effect exerted by a given detractor of attention varies inversely as the degree of attention detracted from. In the present instance, the detractor is a given degree of indefiniteness of outline, the effect of which becomes small when the degree of attention otherwise conditioned is high. The degree of attention tends to be high, in the case of attention to a stimulus, when the difference in intensity between stimulus and background is large, and in the case of attention to a change in stimulus, when the size of the change is large.

A GRADED SERIES OF GEOMETRICAL PUZZLES

BY GRACE HELEN KENT

This series of puzzles is offered as one unit of a group of non-verbal tests to be used for measuring the capabilities of defective children. The work was commenced in the School of Pedagogy of New York University. The general trend of the undertaking has been influenced by three months' experience in the use of the Binet-Simon measuring scale (Goddard's translation) in testing children of the ungraded classes of the public schools of New York and Jersey City. The majority of the children examined were high-grade defectives, but the group included some middle- and low-grade imbeciles and also a few mentally normal children who had been placed in the special classes because of nervous disorders. Nearly all were children of foreign-born parents.

My experience in the use of the Binet test is too limited to justify a general criticism of the method, but I find it necessary to mention four fundamental difficulties which I encountered: (1) The scoring of results is arbitrary, and depends too much upon the personal equation of the examiner. (2) There is little or no uniformity in the tests for children of different levels of intelligence. (3) The test depends too much upon the subject's command of the language in which it is given to be valid for children of immigrants. (4) The subject matter of the test is too far removed from the interests of children to hold their attention, and it frequently requires much urging to induce them to coöperate.

Yerkes[1] has called attention to the lack of uniformity and the inaccuracy of the system of scoring results, and has indicated a way of overcoming these difficulties. He has also shown that the disadvantage which the test imposes upon children of non-English-speaking parents is smaller than

[1] 'The Point Scale: a New Method for Measuring Mental Capacity,' *Boston Medical and Surgical Journal*, December 3, 1914.

might be expected and that it is comparatively constant for children of different ages. In testing children of immigrants by groups, it might be possible to make allowance in the final scoring of results for this disadvantage; but if children are to be tested as individual cases this would not be a safe plan to follow, inasmuch as the deficiency in the language might be so marked as to entirely invalidate the results for the particular child in question.

The fourth objection, the problem of interest, is in my opinion the most vital of all. The purpose of the test is not to determine the child's willingness to answer certain questions, but to determine his ability to answer them. If his coöperation is given unwillingly, the results are misleading. It is plain that Binet recognized this factor, for he called attention to the need of leading the child to regard the test as a game. But this does not depend wholly upon the attitude of the examiner. Some children, especially high-grade defectives, are extremely sensitive to any reminder of their deficiencies. Such a child may be irritated by a question that he cannot answer, and he is liable to feel humiliated when required to answer one that is entirely too easy for him. As it is impossible to determine his level without asking at least a few questions above and below it, the test is something of an ordeal. Young children are sometimes painfully shy in the presence of a stranger, and it requires no small effort to induce them to speak a single word. Such a child may be pleased when a picture is shown, but he becomes self-conscious as soon as he is requested to describe it. He may name a single object, then wait for the question "And what else do you see?" before he ventures to name another. It is possible that a child's willingness or unwillingness to talk to a stranger may be in itself of some significance as an index to his intelligence; but the Binet test is inadequate as a means of determining the exact degree of communicativeness, while it is of course an unnecessarily elaborate method of ascertaining that a child is or is not talkative.

Even the highly practised observer finds it difficult to give scrupulous coöperation in a psychological experiment that

involves distasteful tasks. And in order to obtain full coöperation from immature, defective, insane, or otherwise irresponsible subjects, it is important to offer something that will stimulate a genuine desire to make a good record.

These considerations have led me to undertake the development of a system of non-verbal tests. In attempting this I do not wish to discount the importance of any verbal tests that have been found serviceable in the diagnosis and classification of defectives. In general these tests of action are intended to supplement rather than supplant such verbal tests as are fairly applicable to the subject. It would seem that they should be especially helpful in the study of children of foreign parentage, and possibly in the examination of immigrants at Ellis Island. In the selection of test methods I have adopted provisionally the following rules:

1. Each test is to call for a motor reaction from the subject, rather than for a verbal response. The test itself is to be essentially mental, not motor; but it is to be a test of the subject's ability to perform a certain act which calls for some mental effort, not his ability to answer certain questions.

2. Each test is to require the minimum of verbal explanation on the part of the examiner, so that the subject's attention will not be seriously taxed in merely comprehending the requirements. The instructions are to be so simple that they may be given satisfactorily through an interpreter.

3. Each test must possess sufficient intrinsic interest for the subject to hold his attention and to command his spontaneous coöperation. The performance of the act must possess a certain dignity, so that the subject will not consider it an insult to his intelligence. The accomplishment of the task is to be, from the subject's point of view, an end in itself. The aim is not merely to devise tasks that can be presented attractively by a kindergartener; it is rather to offer something which is in its very nature a game, and so good a game as not to suffer total shipwreck in the hands of the ultra-scientific examiner.

4. Each task is to be capable of being graded, so as to be adaptable to the ability of any subject. The method

must admit of being varied widely in difficulty without affecting the essential nature of the test.

5. Each task must admit of being evaluated by a system that will give partial credit for partial success. The results are to be scored either by a sliding scale or by empirically determined steps.

The unit here presented is well adapted for use among deaf-mutes or foreigners having no knowledge of the language of the examiner, because the instructions may be given wholly by gesture. There are, of course, many similar puzzles already in use; but in view of the present demand for graded tests, it seems probable that this set of puzzles will meet a real need.

The series includes twenty-four puzzles, consisting of rectangular or triangular pieces of wood. For convenience I have arranged the rectangular and the triangular puzzles independently, in parallel series (see plate). Each puzzle when solved forms a square, and is solved by fitting the pieces into a frame ten centimeters square. The puzzles were cut from wood 3/16 inch in thickness. The frame was made by attaching strips of wood 1/16 inch in thickness to the margins of a square of wood, leaving a depression ten centimeters square. The absolute thickness of the wood is presumably of no importance, but it is important that the puzzle pieces should be thicker than the border of the frame, so that any piece which has been placed in the frame may still be easily accessible to the fingers. If desired, cardboard may be used instead of wood. A full set of puzzles, including the frame, may be made very easily by pasting together several thicknesses of light cardboard that can be cut with scissors.

In the presentation of the puzzles to the subject it is well to alternate between rectangles and triangles, because this tends to reduce the effect of practice. The time occupied by the solution of each puzzle is measured by a stop watch. In order to prevent the test from consuming more time than can reasonably be allowed for it, and also to keep a child from becoming unduly fatigued by the effort to solve a puzzle

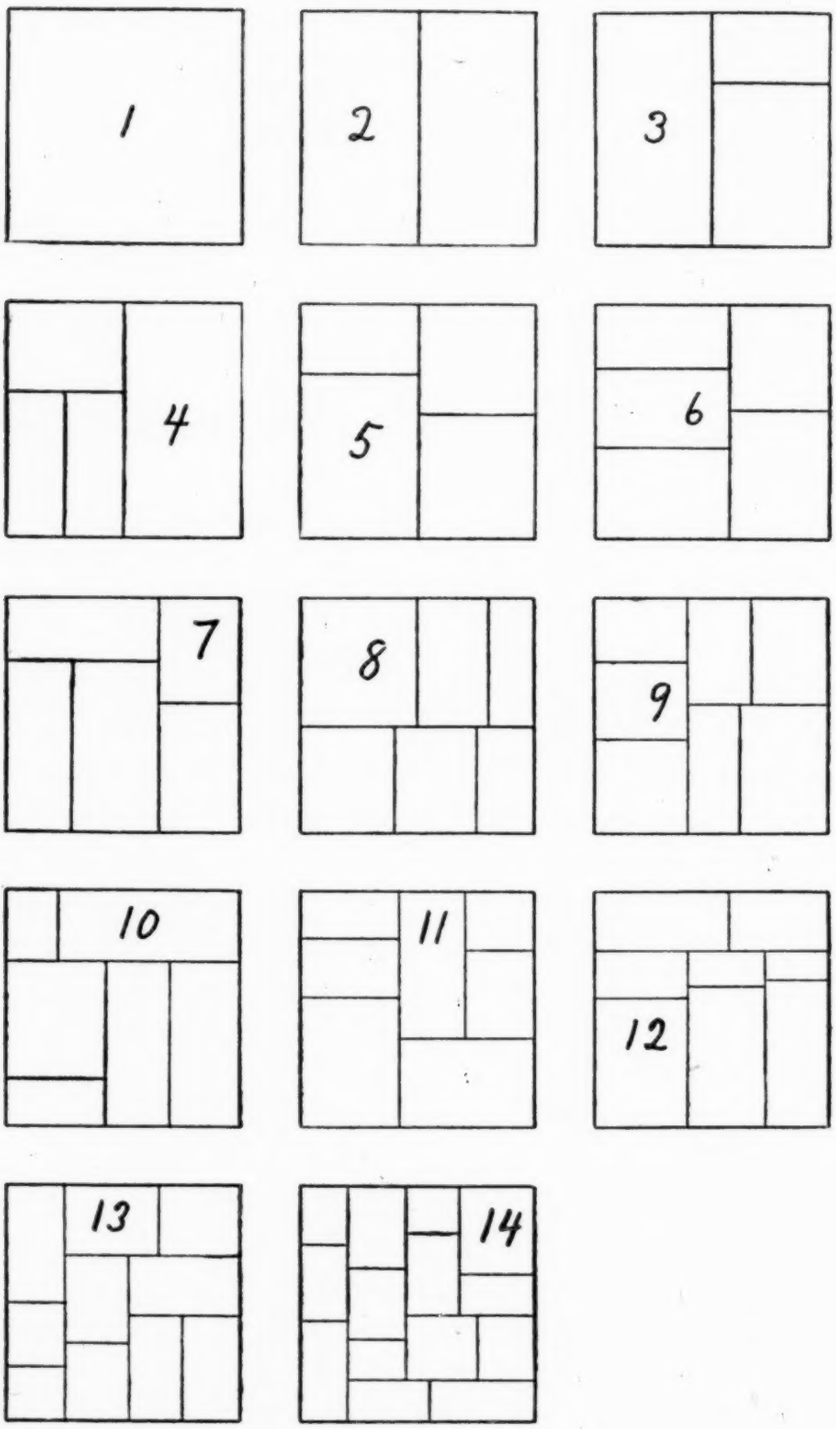

FIG. 1.

that is hopelessly beyond him, I have found it necessary to set an arbitrary time limit. When the gradation of the puzzles has been more thoroughly tested, it may be possible to fix the time limit for each puzzle according to its difficulty. For the present I allow two minutes for each puzzle, and at

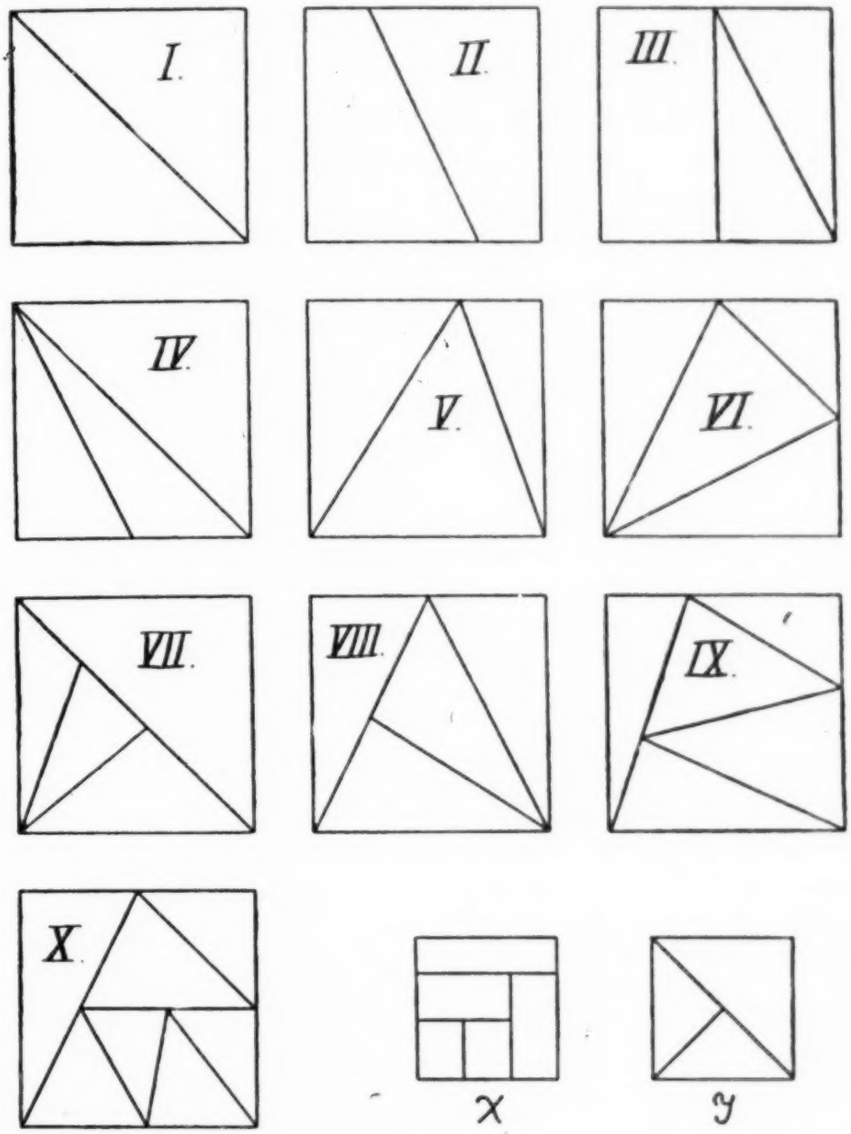

FIG. 2.

the close of that period I interrupt the subject and record that attempt as a failure.

The four puzzles consisting of less than three pieces are designed primarily for infants or subjects of very low-grade

intelligence, and these need not be given to a subject of fair ability. In a routine test I usually begin with 3, 4, or III., and give the puzzles as nearly in the order of difficulty as the alternation between rectangles and triangles permits, until the subject has failed to solve (within the time limit) at least one puzzle of each kind.

The arrangement of the puzzles is somewhat tentative, being based upon results obtained from but twenty-five subjects. In the development of the series preliminary tests have been made upon over one hundred subjects, including sixty-nine defective children. But the results of these tests were obtained under somewhat irregular conditions, and it seems hardly advisable to attempt to make them presentable. I have therefore disregarded them and have made a special series of tests upon twenty-five normal subjects, using the first twenty-five persons who were by any chance available. They range in age from six to seventy-five, and in education from illiteracy to university training.

The results of this series of tests are shown in tabular form. As far as possible, the arrangement of the puzzles is based on the median time record of the twenty-five subjects. The puzzles which were solved within the two-minutes time limit by less than half of the subjects are arranged according to the number of failures which they elicited.

In the early preliminary tests I used no frame, but requested the subject to make a square of the pieces. But the results were very variable, and some of the younger children failed to understand what was meant by a square. The use of the frame is recommended for various reasons, especially because it lowers the scale as a whole. In the grading of a mechanical test it is the lower end of the scale that presents the greatest difficulty. It is well to make the test qualitatively as simple as possible, and then to bring it to any desired degree of difficulty by quantitative differences.

Other things being equal, the difficulty of a puzzle depends upon the number of pieces. But a puzzle made of triangles is far more difficult than one consisting of the same number of rectangles, and there are indications that the two types differ in kind as well as in degree. The correlation between

TABLE I

Rectangular Puzzles				Triangular Puzzles			
Number of Puzzle	Minimal Time Record in Seconds	Median Time Record in Seconds	Failures, Per Cent.	Number of Puzzle	Minimal Time Record in Seconds	Median Time Record in Seconds	Failures, Per Cent.
1	1	2	0	I.	2	5	0
2	2	3	0	II.	2	5	0
3	3	7	0	III.	3	9	4
4	6	10	0	IV.	5	11	0
5	5	11	0	V.	8	16	0
6	7	18	0	VI.	12	42	16
7	10	22	4	VII.	27	—	68
8	10	23	0	VIII.	49	—	76
9	10	28	20	IX.	46	—	88
10	12	31	4	X.	—	—	100
11	20	65	24				
12	26	—	64				
13	—	—	100				
14	—	—	100				

them is apparently rather weak, and it is an open question whether they should be treated as one test or as two tests.

Puzzles 8, 9 and II. are somewhat superfluous, and need hardly be considered as belonging to the series. They are included on the ground that it is frequently convenient to have an extra puzzle which may be used as a control test. In case a child solves puzzle I. very promptly, apparently by chance, it is well to give puzzle II. Puzzles 8 and 9 consist of the same number of pieces respectively as 10 and 11, but the former are simpler of construction. If a subject is able to solve 10 and 11, it is a waste of time to require him first to solve 8 and 9. But if he fails to solve 10, it is only fair to permit him to try the intervening puzzles, so as to insure that his limit has been reached.

In the preliminary tests thirty-eight puzzles have been

tried, and those which yielded the most variable results have been gradually weeded out. The figures *x* and *y* represent two puzzles that proved to be exceptionally unsatisfactory. Both gave a very low minimal time record but a very high percentage of failures, as compared with other puzzles of approximately similar difficulty. This indicates that the element of chance is an important factor in the solution. Puzzle *x* is constructed upon a definite plan, a plan which the subject may grasp at sight, or which he may fail to grasp after several minutes of hard work. Puzzle *y* is apparently very simple, but many subjects are misled by the not unnatural assumption that a right angle properly belongs in a corner of the frame. These two puzzles, however, are useful when there is occasion to give the instructions by gesture. As they are quite unlike any puzzles of the series, they may be used freely by way of illustration.

The puzzles which yield the most uniform results are those which call for a patient and systematic use of the trial and error method. Of course the element of chance cannot be eliminated, but it can be greatly reduced by avoiding any obvious principle of construction. In the rectangular puzzles the pieces should vary in both dimensions, and in the triangular puzzles it is well to depend mainly upon oblique or scalene triangles.

The puzzles at the lower end of the scale have seen considerable use in the tests made upon defective children, and it is significant that puzzles 1 and 2 are the only ones which have met with universal success. I have observed several children work very patiently for the full two minutes with puzzles I. and II., without success. It would seem that a two-piece puzzle must certainly be solved by chance within the time limit, but there are exceptions to this. These puzzles should be tested by using them with normal infants. I have as yet had access to only two infant subjects, one of twenty-three months and one of twenty months. The older child was successful with puzzles 1 and 2, but could not be induced to give sufficient attention to any others. The younger child was successful only with puzzle 1, which is nothing but a form board. Of course the failure to gain the

coöperation of so young a child must be scored against the resources of the examiner in arousing the interest of the child, rather than against the child's ability.

I have not determined at what age a child may be expected to show interest in the puzzles, but I have found it very well developed in two children of six years. Older children are fascinated by them, and it is surprising to see a healthy boy so absorbed in any sedentary occupation. Some of my adult subjects have manifested an interest almost equal to that of children.

Even the defective children showed considerable spontaneity in their reactions to the puzzle test, and I made a practice of interspersing the puzzles among the questions of the Binet test, so as to make the test period as a whole more attractive. I have rarely found a child who would voluntarily abandon the attempt to solve a puzzle. Most children are reluctant to give up when time is called, and I have frequently been moved to promise another trial at the close of the test. A boy of twelve once remained more than an hour, working at the puzzles with absorbing interest and taking little notice of three persons who were watching him. His efforts were remarkably unintelligent, and there was no observable tendency to profit by experience. Because of his great persistency he finally succeeded in solving several of the moderately difficult puzzles; but if requested to try again one which he had just solved, he was as helpless as before.

The subject's mode of reaction is frequently more instructive than the time record, and it should always be observed. I have not made a practice of recording false moves, because I have not found any satisfactory way of classifying them; but I record under 'Remarks' anything noteworthy in the subject's method of working.

The puzzles should be kept behind a screen, and the subject should not be allowed to know how many there are. It is well to explain in advance that nobody is expected to be successful with every puzzle, so that he will not be disconcerted by his first failure. If he drops out in the early part of the series, he should be spared the annoyance of knowing how much he is leaving undone.

The significance of this test as a means of measuring intelligence remains to be seen. But inasmuch as geometrical puzzles are actually being used for clinical purposes, it seems worth while to develop a more systematic method of using them, so as to determine their possibilities and their limitations. The ability to grasp the relation between area and form is a highly specialized function, and its correlation with general intelligence may be comparatively weak. One of my subjects, a man of national reputation in his own field, spent nearly three minutes solving a puzzle which has since been solved in twenty-seven seconds by a child of six years. This puzzle (figure *x*) has since been dropped from the series, but the fact remains that subjects of unquestioned intelligence vary very widely in their possession of the ability to solve puzzles of this type.

If mechanical tests are to be useful for determining intelligence, it is of the utmost importance to have available more and yet more tasks which differ essentially in kind and which call into play widely different types of mental activity. Among the units of such a group there should be pairs which show a strong negative correlation, and the tests should be so varied as to give any subject a fair opportunity to show what kind of ability he may possess.

There will be no attempt at present to standardize this test on a large scale, because it is not certain that it is worthy of being standardized. The present need is for intensive rather than extensive study of test methods. A large number of methods must be tried out in order to find even a few that will be successful, and it is a work of years to find a sufficient number and variety of tasks each of which shall meet all the practical requirements. Standardization, of course, does not render valid a method that is fundamentally defective, but it is all too likely to prolong the life of a criterion which would far better be permitted to die a natural death.

I am offering this unit for what it is worth, possibly a little prematurely, in the hope that its use by others will bring to light its possibilities for improvement. Criticism both of the general plan and of this particular unit will be greatly appreciated.

RELATIVE VALUES OF POINT-SCALE AND YEAR-SCALE MEASUREMENTS OF ONE THOUSAND MINOR DELINQUENTS[1]

BY THOMAS H. HAINES, M.D., PH.D.

Clinical Director of the Bureau of Juvenile Research

In the mental examination of adolescent delinquents, whether in psychological clinics in connection with juvenile courts or in surveys of the populations of reform schools, it has been generally recognized that the Binet-Simon tests are at their best for younger children, and that they afford practically no information as to the variations in mental endowment and character structure of persons who measure above twelve years in mental development. The work of the inventors of this scale and most of those who have sought to restandardize these tests and to make more accurate year scales on the Binet-Simon plan, has been generally confined to testing of children in the primary and grammar grades. Binet and Simon set apart no tests for eleven, thirteen, or fourteen years. The fifteen-year and adult tests remain very poorly standardized.

It is evident that tests devised for and applied to weeding out the feeble-minded from school populations where the oldest children are thirteen or fourteen, are poorly adapted for studying mental make-up of juvenile court cases ranging in age from nine to nineteen, and the majority of whom are adolescents of fifteen, sixteen and seventeen years. It is important to know of these cases whether they are feeble-minded, and, if not of such low mentality as to be unable to manage themselves after the stress of adolescence, what are the peculiarities of mental organization. In other words, the psychologist is called upon for a psychological explanation of the delinquency. The Binet-Simon tests are not accurate

[1] Contributed from the Bureau of Juvenile Research, Columbus, O.

in setting apart the feeble-minded among adolescent delinquents. This is the primary reason for such very different percentages of feeble-minded among juvenile delinquents, obtained by different examiners at different places. Large numbers of our subjects yield Binet-Simon results of more than eleven but under twelve. Other large numbers test twelve flat. Are we to hew rigidly to the line of twelve years? Are all morons who do not make a score of more than twelve years? A glance at our tabulated year-scale ratings of these thousand cases shows at once how a few tenths of a year difference in the upper limit assigned for moronity will make a difference of twenty in the percentage of morons among these offenders. The percentage of moronity, however, is not the important matter to the juvenile court judge or the superintendent of the reform school. In any case feeble-mindedness is a practical concept, like insanity. It is not rigidly definable. One cannot hew accurately to the line in the one case any more than in the other. Society does not wish to confine all psychoses in hospitals for the insane, nor all morons in institutions for feeble-minded. It is only when the mental perversions or the mental deficiences underlie anti-social tendencies, and make the individual a danger or unwarranted expense to society, that he is to be made a custodial case.

What is needed in the practical dealing with the individual delinquent is accurate diagnosis and prognosis. Mental measurements, as accurate as possible, of a variety of mental performances, so these may be compared with average performances of other persons of the same age, sex, and social status, as the individual in question, are the necessary bases of such diagnosis and prognosis. It is important that the same mental performances should be measured by the same standards in all subjects in order that such comparisons may be made. After a number of seemingly normal persons at various stages of mental development have been tested, the average performance, in a given test by a given age, sex, and class, should serve as a unit of measurement of the performance of any person of the same age, sex, and class.

One can state the percentage values of his performances in all the various mental functions covered by the test. By this means a conspectus of the mental efficiency of the individual is afforded. The examiner can then see at a glance what and how great are his points of strength and weakness. Thus will come out reasons for his failure in his given environment (diagnosis) and ground for recommendations as to his future (prognosis and treatment).

The turn given to the Binet-Simon tests by Yerkes and Bridges[1] wherein they select nineteen Binet tests and add one from Wyatt, and devise a system of scoring according to the value of the performance, is founded upon true psychological insight. It provides for a fairly representative mental assessment of the capacities of each individual, and secures the means of comparing his various performances with what might reasonably be expected of a person of his age, sex, and opportunities in life.

In each of the thousand mental examinations of delinquent minors reported herewith, both a point-scale and a year-scale examination were made. The point-scale examinations were conducted throughout in conformity with the Yerkes instructions. The first seven hundred and eighty-six cases were measured by the Binet-Simon year-scale as modified by Goddard.[2] Reference for instructions was made also to the Binet-Simon reports of the tests and instructions.[3] It is so obvious from our own work that many of the Binet tests are misplaced, are too easy or too difficult for the years wherein they are placed, that we determined upon a revised year scale. The remaining two hundred and fourteen of the subjects here reported were measured by our revised year scale, as well as by the point scale. The fact of the necessity for revision of the Binet-Simon scale is neatly demonstrated by

[1] 'A Point Scale for Measuring Mental Ability,' Yerkes, Bridges and Hardwick. Warwick & York, 1915, pp. 168.

[2] 'The Binet-Simon Measuring Scale for Intelligence,' *The Training School*, Jan., 1910, Revised 1911, Henry H. Goddard.

[3] 'A Method of Measuring the Intelligence of Young Children,' Alfred Binet and Th. Simon. Translated by Clara Harrison Town. 'Mentally Defective Children,' Alfred Binet and Th. Simon. Trans. by W. B. Drummond, London, 1914.

Thorndike.[1] He works out medians and averages for the different chronological years, from the results of Goddard, Dougherty, Terman and Childs, Strong, and Brigham. From about nine years to fourteen years the Binet age is lower than the chronological age, and these differences grow larger as age increases. By Binet measurements ten-year-olds are rated 9.8; eleven-year-olds 10.6; twelve-year-olds about 10.9; thirteen-year-olds about 11.4; and fourteen-year-olds about 11.9 years. Stern had gathered evidence on the same point at an earlier date. German and English children show the same defects in the Binet-Simon scale as do American children.[2]

Terman[3] has led out in the most decided revisions and extension of the Binet-Simon year scale. His suggestions were accepted, in very large measure, as to changes in the standards of the Binet tests, and for new tests for the adolescent period. The Knox line test standards, as revised by Pintner,[4] were adopted as follows: V. years, one of *X* and *Y*, correct; VI., one of *B*, *C*, and *D*, correct; VII., two of *B*, *C*, and *D*, correct; and X., one of *E*, *F*, and *G*, correct. These tests commend themselves, because they serve as measurements of a species of practical logic, and have no dependence upon formal education. They test attention (concentration and scope) and the capacity to get and hold a *plan* (*constructive imagination*). They also test capacity to execute the plan—*control of voluntary movements*—or manual dexterity.

When applying the Binet tests, as revised by Goddard, we made very little use of the 'XV.-year' tests, and none of the 'Adult' tests. 'Interpretation of Pictures' was scored in routine. 'Changing Clock Hands' and 'Opposites' were

[1] 'The Significance of the Binet Mental Tests,' Edward L. Thorndike, Ph.D., *The Psy. Clinic*, VIII., Dec. 15, 1914.

[2] 'The Psychological Methods of Testing Intelligence,' Wilhelm Stern. Translated by G. M. Whipple. Warwick & York, Baltimore, 1914, p. 48.

[3] See *Journal of Educational Psychology*, 1912 (III.). The writer is greatly indebted to Professor Terman for copies of 'Record Blanks' and a 'Guide for the Use of the Stanford Revision and Extension of the Binet-Simon Measuring Scales of Intelligence.'

[4] 'The Standardization of Knox's Cube Test,' Rudolph Pintner, *The Psychological Review*, Sept. 1915, pp. 377–401.

sometimes used. Successes in any of these were commonly reckoned at 0.4 of a year each. They were thus added to the lower attainments. If the score thus mounted a fraction of a year above XII. it was generally designated merely 12.0 +. In the use of the revised year scale, the score was regularly counted, two tenths of a year for each test passed beyond the basal year, up to and including twelve years, and then four tenths of a year for each test passed. On this revised scale we had five tests for each year, III. to XII. inclusive, and five each for XIV., XVI., and XVIII.

Table I. presents in parallel columns and in year groups, the point-scale and year-scale ratings of six hundred and seventy-one delinquent boys at the Boys' Industrial School near Lancaster, Ohio. The scores are arranged within the year groups in the order of point-scale attainments. The chronological age in each case is that of the nearest birthday on the day of the examination. Thus, the XIV.-year column comprises all those between thirteen years and six months, and fourteen years and six months when examined. In general, the examinations were made soon after admission. Those year-scale ratings made by our revised year scale are marked with an asterisk. All year-scale ratings not so marked are measured by the Goddard revision of the Binet-Simon scale.

Table II. presents, in exactly the same way, the results from mental examinations of three hundred and twenty-nine delinquent girls at the Girls' Industrial Home, near Delaware, Ohio. The examinations were made, in considerable part, at both institutions, by the writer. About one half of the boys were examined by Miss Emilie M. Dietz, and about one third of the girls by Miss Alida C. Bowler. The high order of intelligence and conscientious devotion to the work contributed by each of these coworkers is gratefully acknowledged.

The most liberal criteria of feeble-mindedness accepted by so-called Binet examiners are these: All persons who are four years behind their chronological ages in mental development, and all persons who are sixteen or more, and are less than

TABLE I

POINT-SCALE SCORES OF SIX HUNDRED AND SEVENTY-ONE DELINQUENT BOYS, ARRANGED IN YEAR GROUPS IN THE ORDER OF THE SCORES, WITH THE YEAR-SCALE SCORES OF EACH INDIVIDUAL IMMEDIATELY TO THE RIGHT OF HIS P.S. SCORE

Year-scale scores, marked with asterisk (*) preceding, are by the revised year scale of the Bureau of Juvenile Research. Others by Goddard's revision of the Binet-Simon scale. The Yerkes-Bridges *averages* per year groups of Cambridge children of English-speaking parents are indicated thus (″) in the columns; P.S. scores, 20% below average, thus (=); 25% below average, thus (–); and 30% below average, thus (×).

10 Yrs.		11 Yrs.		12 Yrs.		13 Yrs.		14 Yrs.		15 Yrs.		16 Yrs.		17 Yrs.		18 Yrs.		19 Yrs.	
P.S.	Y.S.	P.S.	Y.S.	P.S.	Y.S.	P.S.	Y.S.	P.S.	Y.S.	P.S.	Y.S.	P.S.	Y.S.	P.S.	Y.S.	P.S.	Y.S.	P.S.	Y.S.
28	6.6	35	7.6	42	7.2	32	7.5	31	7.6	32	8.0	32	8.5	50	9.8	39	8.8	–25%–	
×30%×		38	8.2	42	8.6	40	7.4	41	8.0	35	7.8	33	6.6	50	*10.0	41	9.0	68	10.8
–25%–		×30%×		42	*8.6	41	8.6	41	8.8	36	7.8	46	8.4	51	8.6	56	9.4	68	10.8
		44	8.1	45	8.7	42	8.6	41	9.0	41	8.6	46	9.6	51	9.2	56	9.6	=20%=	
48	8.0	44	8.4	48	9.6	42	9.5	42	*8.4	45	8.4	47	9.0	51	9.8	56	9.6	78	11.7
=20%=		44	9.2	51	9.8	43	7.6	42	8.4	45	9.2	51	9.4	52	9.9	57	9.7	″Av″	
50	9.0	–25%–		×30%×		44	8.4	43	8.6	46	9.5	51	9.9	52	10.0	57	10.2		
51	9.7	49	8.6	55	10.0	44	*9.0	45	9.4	48	9.4	52	9.1	53	10.8	58	10.0		
53	10.0	49	9.0	56	*9.2	46	8.2	46	8.7	49	9.4	53	8.4	54	9.2	59	*8.8		
54	9.4	50	9.2	56	9.2	47	8.8	46	9.1	50	*7.8	53	9.4	54	9.5	59	9.4		
56	9.8	51	8.6	57	*9.4	48	9.8	47	*9.4	51	9.8	53	9.6	54	10.1	61	10.2		
59	9.2	=20%=		57	10.4	49	9.0	47	9.6	53	9.4	58	10.0	55	8.4	×30%×			
61	9.2	54	9.0	–25%–		51	9.4	48	9.6	53	9.4	×30%×		55	9.2	62	9.6		
61	9.8	55	10.1	58	9.8	51	9.8	49	9.4	53	*10.0	59	10.6	55	9.3	62	10.0		
″Av″		56	9.0	58	10.0	52	8.8	49	10.0	54	8.9	60	9.6	55	10.0	64	9.2		
69	10.8	56	10.0	58	10.0	53	9.8	51	9.6	54	9.0	60	10.4	56	9.8	–25%–			
70	10.6	58	10.1	60	9.8	54	8.6	51	9.8	54	9.2	61	10.3	56	9.9	67	11.0		
		59	9.4	60	10.2	54	10.0	52	9.2	54	9.4	62	9.3	56	10.6	68	10.4		
		60	10.3	61	10.8	54	10.2	52	9.2	54	10.3	62	9.4	57	9.3	68	10.4		
		61	10.2	=20%=		×30%×		53	9.6	55	8.5	62	10.2	57	9.4	68	10.6		
		61	10.5	62	10.0	59	9.6	53	9.8	55	9.0	62	10.2	57	9.6	68	10.8		
		62	10.5	63	9.6	59	10.1	55	9.0	55	9.2	62	10.4	57	*10.6	68	10.9		
		″Av″		63	10.1	59	10.2	55	10.1	55	9.9	–25%–		58	9.7	68	11.1		
		65	10.4	63	10.4	59	10.3	56	9.6	56	10.0	63	9.5	58	9.7	69	10.6		
		65	10.5	65	9.6	–52%–		×30%×		57	9.2	63	10.0	58	9.8	69	11.0		
		66	10.7	65	11.0	61	9.4	57	9.4	57	9.6	63	10.2	58	10.4	69	*11.8		
		67	9.8	66	10.0	61	*10.0	57	9.5	57	9.6	63	10.6	58	10.9	70	10.8		
		71	10.7	66	10.2	61	10.1	58	9.2	57	9.6	63	10.7	59	11.0	70	11.0		
		73	10.6	67	10.5	63	9.6	58	9.6	57	9.8	63	10.9	×30%×		70	11.4		
		74	10.7	67	11.0	=20%=		58	*10.0	×30%×		64	*10.0	62	10.0	70	*12.0		
				69	*11.6	64	10.7	58	*11.4	58	10.0	64	*10.0	62	10.4	=20%=			
				71	10.4	64	10.7	59	10.0	59	10.4	64	10.6	62	10.8	71	10.7		
				71	11.2	65	10.8	59	10.2	59	10.6	64	10.6	63	10.1	71	10.8		
				71	11.4	65	*11.0	60	9.4	59	10.7	65	10.0	63	11.0	72	10.7		
				72	10.8	66	10.1	60	9.9	60	9.8	65	11.2	64	9.6	72	11.4		
				75	10.8	68	10.7	60	10.6	60	10.3	65	11.2	64	10.2	74	11.2		
				76	10.2	68	10.8	–25%–		60	10.8	66	10.2	64	10.4	75	11.2		
				76	11.7	68	*11.0	61	10.4	61	9.8	66	10.9	64	10.4	75	11.3		
				″Av″		69	10.4	61	10.8	61	9.8	67	10.5	64	10.6	75	11.7		
				77	10.6	70	10.6	62	9.8	61	10.0	67	11.2	64	10.6	77	11.6		
						70	10.7	62	10.0	61	10.2	=20%=		64	10.6	77	12.0+		
						70	11.0	62	10.0	–25%–		68	10.4	64	10.7	78	11.2		
						70	11.0	63	9.8	62	10.0	68	10.6	64	10.9	78	11.6		

TABLE I—*Continued*

10 Yrs.		11 Yrs.		12 Yrs.		13 Yrs.		14 Yrs.		15 Yrs.		16 Yrs.		17 Yrs.		18 Yrs.		19 Yrs.	
P.S.	Y.S.	P.S.	Y.S.	P.S.	Y.S.	P.S.	Y.S.	P.S.	Y.S.	P.S.	Y.S.	P.S.	Y.S.	P.S.	Y.S.	P.S.	Y.S.	P.S.	Y.S.
						70	11.0	64	10.2	62	10.0	68	10.5	−25%−		79	11.5		
						72	10.4	64	10.6	62	10.4	68	10.9	65	10.6	82	11.0		
						72	10.8	64	*10.6	63	9.7	69	10.2	66	9.6	82	11.5		
						73	11.3	64	*10.6	63	9.9	69	10.3	66	9.6	82	11.8		
						73	11.5	64	*10.8	63	10.0	69	10.4	66	10.4	83	11.0		
						73	11.6		=20%=	63	10.0	69	10.8	67	9.8	83	12.0+		
						74	11.2	65	10.7	63	10.2	70	10.3	67	9.8	85	11.2		
						75	11.0	66	9.8	63	*10.4	70	10.6	67	10.5	85	11.7		
						75	11.6	66	9.8	63	10.9	70	10.7	68	9.7	85	12.0		
						78	11.5	66	11.3	64	9.2	70	11.0	68	10.4	86	11.6		
						78	*12.2	67	10.2	64	10.1	71	9.8	68	10.4	86	12.0		
							"Av"	67	10.4	64	10.4	71	10.4	=20%=			"Av"		
						79	11.0	67	10.4	65	10.0	71	10.4	69	10.4	88	11.8		
						79	11.6	67	10.6	65	10.0	71	10.6	69	10.9	88	12.0+		
						81	11.2	68	9.8		=20%=	72	10.8	69	11.1	89	11.8		
						81	11.4	68	10.2	66	9.8	72	11.0	69	11.7	89	*14.4		
						81	11.4	68	10.4	66	10.0	72	11.0	70	10.5	90	11.6		
						86	11.7	69	11.2	66	10.4	72	11.0	70	11.2	90	12.0+		
						93	12.0+	69	11.6	66	10.4	72	11.7	70	11.2	90	12.0+		
								69	*12.4	66	10.4	73	11.0	71	10.7	90	12.0+		
								70	10.4	66	10.8	73	11.0	71	11.0	91	*16.4		
								70	10.8	67	9.8	73	11.6	71	11.4	92	12.0		
								70	11.4	67	10.6	74	10.4	72	10.4	92	12.0+		
								71	10.2	68	*9.8	74	10.6	72	11.0	93	12.0+		
								71	11.0	68	10.4	74	10.6	72	11.0	94	12.0+		
								71	11.0	68	10.4	74	11.2	72	11.2	96	12.0		
								71	11.4	68	10.4	75	11.2	72	11.2	97	12.0+		
								72	10.6	68	10.6	75	11.5	72	11.6	97	12.0+		
								73	11.2	68	10.6	75	12.0	73	11.6				
								74	11.0	69	9.7	76	11.4	74	11.1				
								74	11.2	69	10.1	76	11.0	74	11.2				
								76	10.4	69	10.7	77	11.4	75	11.0				
								76	10.6	69	10.8	77	11.7	75	11.6				
								76	11.1	69	11.0	78	11.2	76	10.4				
								77	11.7	69	11.1	78	11.8	76	11.1				
								77	12.0	71	9.8	79	10.6	76	11.4				
								78	11.4	71	10.8	79	10.6	76	11.4				
								79	11.2	72	10.2	79	12.0	76	*11.6				
								79	11.2	72	10.6	79	12.0	76	11.6				
								80	10.6	72	11.0	80	11.2	76	11.6				
								80	10.8	73	10.4	80	11.4	76	11.6				
								80	11.4	73	10.9	80	11.6	76	11.6				
								80	11.4	73	11.0	81	11.2	76	11.7				
									"Av"	73	11.1	81	11.2	77	11.5				
								82	11.4	73	11.2	81	11.4	77	11.6				
								83	11.2	73	*11.4	81	11.6	77	11.7				
								83	11.2	73	11.5	82	11.6	78	10.8				
								83	11.6	74	11.6	82	11.7	78	11.2				
								83	11.6	75	10.6	83	11.0	78	11.6				
								83	*13.2	75	11.0	83	11.6	78	*12.8				
								85	11.9	75	*12.6	83	12.0	79	10.9				
								87	11.4	76	10.8	83	12.0	79	11.0				
								88	12.0+	76	11.2	83	12.0	79	11.2				
								92	*14.0	76	11.6	83	12.0+	79	11.4				

TABLE I—*Continued*

10 Yrs.		11 Yrs.		12 Yrs.		13 Yrs.		14 Yrs.		15 Yrs.		16 Yrs.		17 Yrs.		18 Yrs.		19 Yrs.	
P.S.	Y.S.	P.S.	Y.S.	P.S.	Y.S.	P.S.	Y.S.	P.S.	Y.S.	P.S.	Y.S.	P.S.	Y.S.	P.S.	Y.S.	P.S.	Y.S.	P.S.	Y.S.
								93	12.0+	76	11.7	83	*12.8	79	11.4				
										77	11.2		"Av"	79	11.6				
										77	11.2	84	11.4	80	11.6				
										77	11.4	84	12.0+	80	11.6				
										78	11.2	84	12.0+	80	11.9				
										78	11.6	85	11.4	80	*12.8				
										78	*12.8	85	12.0	81	11.4				
										79	10.8	85	12.4	82	11.0				
										79	10.8	85	12.4	82	11.4				
										79	11.2	86	11.4	82	11.8				
										79	11.4	86	11.6	82	11.9				
										79	11.6	86	11.8	82	12.0				
										80	11.4	87	12.0	82	12.0+				
										80	11.4	87	12.0+	83	11.9				
										80	11.6	89	12.0	83	12.0				
										80	12.0	90	12.0	84	11.4				
										81	11.0	90	12.0+	84	11.6				
										81	11.4	91	12.0	84	12.0+				
										81	11.4	92	11.4	85	12.0				
										81	11.4			85	12.0				
										81	11.7			85	12.0+				
											"Av"				"Av"				
										82	11.2			86	11.4				
										82	11.6			88	11.8				
										82	11.9			88	11.9				
										82	12.0			89	12.0+				
										83	11.2			89	*14.8				
										83	12.0			90	12.0				
										84	11.2			90	12.0+				
										84	11.5			90	12.0+				
										84	12.0+			91	12.0				
										84	12.0+			91	12.0+				
										86	11.6			91	*13.4				
										87	11.6			93	11.6				
										88	11.6								
										88	11.6								
										88	12.0								
										88	12.0+								
										88	12.0+								
										89	11.4								
										89	11.6								
										91	11.6								
										94	12.0+								

twelve in mental development, are classed as definitely feeble-minded. The rigid application of these criteria of feeble-mindedness shows five hundred and seventy of these thousand delinquents to be feeble-minded. Had we examined the last two hundred and fourteen also by the Goddard revision of the Binet scale, we should probably have a yet larger percentage of feeble-minded. The actual numbers

TABLE II

POINT-SCALE SCORES OF THREE HUNDRED AND TWENTY-NINE DELINQUENT GIRLS, ARRANGED IN YEAR GROUPS IN THE ORDER OF THE SCORES, WITH THE YEAR-SCALE SCORES OF EACH INDIVIDUAL IMMEDIATELY TO THE RIGHT OF HER P.S. SCORE

Year-scale scores, marked with asterisk (*) preceding, are by the revised year scale of the Bureau of Juvenile Research. Others by Goddard's revision of the Binet-Simon scale. The Yerkes-Bridges *averages* per year groups of Cambridge children of English-speaking parents are indicated thus (") in the columns; P.S. scores, 20% below average, thus (=); 25% below average, thus (–); and 30% below average, thus (×).

10 Yrs.		11 Yrs.		12 Yrs.		13 Yrs.		14 Yrs.		15 Yrs.		16 Yrs.		17 Yrs.		18 Yrs.		19 Yrs.	
P.S.	Y.S.	P.S.	Y.S.	P.S.	Y.S.	P.S.	Y.S.	P.S.	Y.S.	P.S.	Y.S.	P.S.	Y.S.	P.S.	Y.S.	P.S.	Y.S.	P.S.	Y.S.
39	7.6	=20%=		36	7.2	45	*8.4	38	9.2	36	*7.6	20	*5.8	35	*7.4	47	8.0	47	*8.6
×30%×		53	*9.2	×30%×		50	*9.0	40	*7.8	38	7.9	38	*6.8	47	*8.4	47	*8.8	54	9.3
		59	*9.0	–25%–		×30%×		43	*7.8	38	8.8	38	*8.0	49	*9.2	52	*9.2	58	9.7
		"Av"		=20%=		58	9.4	44	*9.4	45	*9.6	40	*6.8	50	8.8	55	9.7	×30%×	
				65	*10.4	58	*10.0	45	*8.0	48	9.0	41	8.9	50	9.0	55	9.9		
				73	11.0	59	9.8	47	*7.8	48	*9.2	46	*8.8	50	9.2	56	9.3		
				"Av"		59	*10.0	48	9.0	49	*9.8	48	9.1	51	*8.6	58	*9.6		
				80	*11.2	–25%–		51	8.3	50	*8.4	49	*8.4	54	*9.1	58	9.7		
						60	9.4	52	8.8	50	9.7	50	*9.6	55	9.7	59	9.8		
						60	*10.6	54	*9.2	53	*9.6	51	9.0	55	*9.0	×30%×			
						61	*9.4	55	9.4	55	9.5	54	9.4	57	*8.8	65	*11.2		
						=20%=		56	*9.6	56	*10.8	56	10.2	57	9.8	–25%–			
						64	*9.6	56	*10.0	57	9.5	×30%×		58	9.6	66	*11.0		
						64	*12.0	×30%×		57	* 9.8	60	*10.4	58	10.3	67	*10.6		
						65	*11.6	58	*10.8	×30%×		61	9.5	59	*9.2	67	*12.0		
						71	11.3	59	*9.4	58	*10.4	61	*10.0	×30%×		68	*11.2		
						73	*12.0	60	*10.6	60	9.7	61	*10.4	61	10.0	68	*11.4		
						76	*10.6	–25%–		60	*9.8	62	9.5	62	*9.6	70	*11.2		
						"Av"		61	9.0	60	10.5	62	9.9	62	*9.6	=20%=			
						82	12.0+	61	11.0	61	10.0	62	10.7	63	9.2	71	*10.2		
						84	12.0+	61	11.1	61	10.2	–25%–		64	9.8	71	*11.8		
								62	*10.0	61	10.6	63	10.1	64	*10.0	72	*12.0		
								63	*10.6	–25%–		63	*10.6	64	11.5	73	11.5		
								63	11.0	62	*9.4	64	10.8	–25%–		79	*13.4		
								=20%=		62	10.1	64	*12.8	65	10.6	80	*11.8		
								67	*9.6	63	*9.8	65	11.0	66	9.8	81	12.0+		
								67	*10.8	63	10.1	65	*12.2	66	*11.0	83	*12.0		
								68	10.5	63	10.2	66	*11.0	66	*11.2	83	*12.8		
								68	*11.0	63	*10.8	=20%=		67	*10.6	85	*13.4		
								68	11.3	63	10.8	68	*10.2	67	11.0	86	12.0		
								70	*11.4	64	*10.2	68	10.8	68	*10.2	86	12.0		
								72	9.8	64	*11.2	68	11.0	68	*12.2	87	*13.2		
								72	11.0	65	9.6	69	10.0	=20%=		"Av"			
								72	*12.8	65	*10.6	69	*10.6	69	*11.0	89	*14.6		
								74	*10.6	65	11.2	71	11.2	71	*11.0	90	12.0		
								74	11.0	=20%=		72	11.0	71	*11.4	90	*14.8		
								75	*10.8	66	10.7	72	11.5	73	*11.2	92	12.8		
								75	*11.2	67	*10.2	73	11.1	75	11.5				
								76	*13.2	67	*11.2	73	*12.1	75	*11.6				
								77	*11.6	68	*10.6	74	*10.8	75	*12.1				
								78	11.2	69	10.2	74	11.4	75	*13.4				
								79	*12.2	69	10.4	74	11.4	76	*10.8				
								79	*12.8	69	*10.8	74	*12.4	76	*11.6				

TABLE II—*Continued*

10 Yrs.	11 Yrs.	12 Yrs.	13 Yrs.	14 Yrs.	15 Yrs.	16 Yrs.	17 Yrs.	18 Yrs.	19 Yrs.
P.S. Y.S.	P.S. Y.S.	P.S. Y.S.	P.S. Y.S.	P.S. Y.S.	P.S. Y.S.	P.S. Y.S.	P.S. Y.S.	P.S. Y.S.	P.S. Y.S.
				80 11.5	70 11.1	76 11.2	77 11.6		
				"Av"	70 *12.4	76 *12.0	77 11.7		
				83 *12.8	73 11.1	77 12.0	77 12.0		
				83 *14.0	73 11.2	77 12.0+	78 11.8		
				84 12.0+	73 11.5	77 *12.1	78 *12.2		
				86 12.0+	73 *11.6	77 *12.6	79 *13.8		
					73 11.7	78 11.7	80 *11.8		
					73 *12.0	78 11.8	80 12.0		
					73 *12.0	79 11.4	80 *12.6		
					74 *11.9	79 11.4	80 *12.6		
					74 12.0	79 12.0	81 11.3		
					75 *10.8	79 *14.0	81 12.0		
					76 12.0+	80 11.3	81 12.0+		
					77 11.1	80 *11.8	81 12.0+		
					77 11.7	80 12.0	81 *13.4		
					77 12.0	80 12.0+	83 12.0+		
					77 *12.4	81 11.1	83 *14.4		
					78 11.0	81 *13.4	84 12.1		
					78 *12.6	82 11.8	85 *14.0		
					79 *14.2	82 12.0	"Av"		
					80 *12.8	82 12.0+	86 12.0+		
					80 *13.2	82 12.0+	86 12.0+		
					81 11.5	82 *13.2	87 *13.8		
					81 12.0+	83 11.8	88 *13.6		
					81 *12.2	83 *12.0	88 *14.0		
					"Av"	"Av"	90 11.0		
					82 *12.4	84 *11.2	90 11.4		
					83 12.4	84 11.7	94 12.0+		
					83 *13.8	85 11.7	97 *15.2		
					84 *12.0	85 12.0+			
					84 *12.6	85 12.0+			
					85 *14.4	85 *13.2			
					87 12.0	86 *16.0			
					88 12.0+	87 12.0+			
					88 12.0+	87 12.0+			
					88 *12.8	90 12.0+			
					89 *14.6	90 *13.2			
					95 *14.6	90 *13.4			
						91 12.0+			
						94 *14.0			

thus classed as feeble-minded in each year and sex group, together with percentages of feeble-minded in each group, are given in Table V. Earlier examinations of delinquents at these same institutions are stated by Goddard[1] to have yielded seventy per cent. feeble-minded. By the same table several other reform schools have been found to have eighty per cent. and more, of feeble-minded. No one can doubt

[1] 'Feeble-Mindedness; Its Causes and Consequences,' Henry Herbert Goddard, Ph.D., New York, 1914, p. 9.

the average mental caliber of the population of one reform school differs widely from that of another, and that the mentality of the same school will differ from one year to another. But such a general prevalence of feeble-mindedness among delinquents, almost identifying delinquency with feeble-mindedness, certainly demands the application of some critical judgment, and serious inquiry as to what is really meant by feeble-mindedness. The showing already

TABLE III

GIVES NUMBERS, AVERAGES AND MEDIANS FOR EACH YEAR GROUP OF (1) BOYS, (2) GIRLS, AND (3) BOYS AND GIRLS, AND (4) NUMBERS AND AVERAGES FOR YEAR GROUPS OF THE YERKES-BRIDGES CHILDREN OF ENGLISH-SPEAKING PARENTAGE

Age	Ohio Delinquent Males			Ohio Delinquent Females			Ohio Delinquents Male and Female			Yerkes-Bridges Male and Female English	
	No.	Aver.	Median	No.	Aver.	Median	No.	Aver.	Median	No.	Aver.
4	...	...	...	...	...	...	...	...	...	3	17
5	...	...	...	...	...	...	...	...	...	28	22
6	...	...	...	...	...	...	...	...	...	55	29
7	...	...	...	...	...	...	...	...	...	48	35
8	...	...	...	...	...	...	...	...	...	47	41
9	...	...	...	...	...	...	...	...	...	43	56
10	12	55.8	55.0	1	39.0	39.0	13	54.5	54.0	53	62
11	26	56.4	57.0	2	56.0	56.0	28	56.4	57.0	55	65
12	36	61.4	62.5	4	63.5	69.0	40	61.6	63.0	40	77
13	58	62.7	64.5	17	64.1	61.0	75	63.0	64.0	43	79
14	94	64.7	65.5	45	64.5	67.0	139	64.6	66.0	37	81
15	136	68.2	68.0	77	68.3	69.0	213	68.2	69.0	16	82
16	112	71.4	71.0	79	71.1	74.0	191	71.3	73.0	...	...
17	127	71.0	72.0	68	71.0	74.0	195	71.0	72.0	...	...
18	67	75.0	75.0	33	71.4	71.0	100	73.8	72.5	...	...
19	3	71.3	68.0	3	53.0	54.0	6	62.2	63.0	...	...
Totals	671	...	...	329	...	...	1,000	...	...	468	...

made by Thorndike and Stern, as to the inaccuracy of Binet ratings of mentality above nine years, and the question as to the meaning of *twelve-year mentality* in an adult, whether or not this is the safely practical line of demarcation between the feeble-minded and those who can efficiently manage themselves, have likewise prepared us to be suspicious of such large percentages of *feeble-minded* among delinquents.

Turning now to the consideration of the point scale readings of these delinquents, let us consider first the averages

and medians of their point-scale scores for year and sex groups, and the distribution of the cases above and below these, and the relations of these averages to the averages of Cambridge school children. These averages and medians are presented in Table III.

In the years directly comparable with the Yerkes-Bridges results (10 to 15 inclusive) the averages of the delinquents are, for boys and girls alike, considerably lower than the averages for Cambridge school children. Assuming norms of 84, 86, 88, and 88, for the years 16, 17, 18, and 19, respectively, as seems reasonable from Yerkes's report of examinations of mill operatives,[1] we find that these years' averages are likewise considerably lower for the delinquents. Taking the averages of boys and girls together, the year groups of delinquents from 10 to 19 inclusive, show retardations, year by year, of $7\frac{1}{2}$, 9, 15, 16, $16\frac{1}{2}$, 14, $12\frac{1}{2}$, 15, 14, and 26 points. In other words, the 10-year-olds score points for a trifle under nine; the eleven, for about nine; the twelve, for about ten; the thirteen, for ten and one third; the fourteen, for eleven; the fifteen, for eleven and one third; the sixteen and seventeen, for eleven and one half; the eighteen, for eleven and three fourths years. This signifies that our group of delinquents is loaded with feeble-minded, considerably beyond the load carried by the average school population.

The comparisons of boys and girls do not result in any decided superiority for either sex at any age. This also holds in spite of the fact that nearly three times as many boys as girls are committed by the same courts every year. By averages, the girls have a slight superiority at twelve and thirteen, and the boys at eighteen. The figures are very nearly the same for years fourteen to seventeen, inclusive, and for eleven. Groups are too small, for years ten and nineteen, to signify anything. The medians suffice only to show there is nothing significant in these differences in averages for the sex groups. Another piece of evidence indicating the weighting or loading of these delinquent

[1] See p. 90 of 'A Point Scale for Measuring Intelligence.' Twenty-five mill operatives of ages from 17 to 27, average 88.3 points.

groups with the feeble-minded, emerges from a comparison of the numbers of boys and girls among delinquents, and in the Yerkes-Bridges findings, who are more than 25 per cent. above, and more than 25 per cent. below the averages for their particular year groups. The material for this comparison is presented in Table IV.[1]

While the Cambridge school children from English-speaking homes yield the same numbers (46), 25 per cent. below average, and 25 per cent. above average, the delinquent minors under consideration yield 102 25 per cent. or more below the averages of their respective year groups, and only 76 who are 25 per cent. or more above the averages for their groups. Further, the six eighteen-year-olds are all low and yield an average quite out of the line of progression of the averages of the earlier year groups. Taking the seventeen-year average as appropriate for 18 years, these figures change to 75 and 104.

These two lines of evidence from the side of point-scale scores—lower year group averages than those of Yerkes and Bridges, and the much larger numbers of scores 25 per cent. below the averages for their groups than scores 25 per cent. above same—taken in connection with the Binet findings, certainly leave no room for doubt that the groups under consideration are overloaded with individuals of poor mental endowment. These reform-school populations are *selected.* Among them, *lower than average* mental equipment occurs much more frequently than in unselected groups.

In order to assess the point-scale findings in such a population we should compare the scores with averages from typical unselected groups. Such a group we have in the four hundred and sixty-eight Cambridge school children from homes where English is spoken. The question immediately arises, when we set about such an assessment of the mental ability of any given individual, What amount of retardation signifies a mental deficiency such as will make it impossible for the individual to manage himself within the lines of propriety as a self-sustaining member of society?

[1] See 'A Point Scale for Measuring Mental Ability,' pp. 56 and 57.

TABLE IV

GIVES, UNDER AGE AND SEX, POINT-SCALE SCORES OF ALL INDIVIDUALS OF CAMBRIDGE SCHOOL CHILDREN, AND OF DELINQUENT MINORS, WHICH ARE 25% OR MORE ABOVE AND 25% OR MORE BELOW THE AVERAGES OF THEIR RESPECTIVE AGE GROUPS

Age	4		5		6		7		8		9		10		11		12		13		14		15		16		17		18		19		Totals
Sex	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	
English-speaking Cambridge children 25% or more *above* the average.[1]	23	..	26	30	36	38	41	47	57	50	70	70	84	77	84	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	46
	..	..	31	34	38	39	41	48	58	52	71	74	..	77	85	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	
	..	..	..	35	38	44	42	48	..	56	..	77	..	79	89	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	
	..	..	..	..	39	44	42	49	..	57	..	..	..	80	93	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	
	..	..	..	..	39	..	43	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	
	..	..	..	..	47	..	45	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	
English-speaking Cambridge children 25% or more *below* the average.[1]	12	..	11	11	11	13	14	21	21	15	32	21	44	39	45	41	53	..	..	38	61	54	..	55	..	..	..	..	..	..	..	..	46
	..	..	15	13	15	15	17	23	30	25	..	38	48	40	48	..	56	..	..	46	..	..	..	..	..	..	..	..	..	..	..	..	
	..	..	..	18	21	21	20	25	30	25	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	
	..	..	..	..	..	22	23	..	31	29	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	
	..	..	..	..	..	..	23	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	
Delinquent minors 25% or more *above* the averages for delinquents.	..	..	..	..	..	..	..	..	..	..	..	..	69	..	71	..	77	80	79	82	82	80	86	87	90	90	89	90	93	..	78	..	76
	..	..	..	..	..	..	..	..	..	..	..	..	70	..	73	..	..	..	79	84	83	83	87	88	90	90	89	90	94	..	..	..	
	..	..	..	..	..	..	..	..	..	..	..	..	..	..	74	..	..	..	81	..	83	83	88	88	91	90	90	94	96	..	..	..	
	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	81	..	83	84	88	88	92	91	90	97	97	..	..	..	
	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	81	..	83	..	88	89	..	94	90	..	97	..	..	..	
	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	86	..	83	..	88	95	..	..	91	..	..	..	..	..	
	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	93	..	85	..	88	..	..	..	91	..	..	..	..	..	
	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	87	..	89	..	..	..	91	..	..	..	..	..	
	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	88	..	89	..	..	..	93	..	..	..	..	..	
	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	92	..	91	..	..	..	..	..	..	..	..	..	
	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	93	..	94	..	..	..	..	..	..	..	..	..	

TABLE IV—*Continued*

Age.	4		5		6		7		8		9		10		11		12		13		14		15		16		17		18		19		Totals
Sex	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	
Delinquent minors 25% or more *below* the averages for delinquents.	..	..	..	..	..	..	..	..	..	..	..	..	28	39	35	..	42	36	32	45	31	38	32	36	32	20	50	35	39	47	..	..	102
	..	..	..	..	..	..	..	..	..	..	..	..	..	..	38	..	42	..	40	..	41	40	35	38	33	38	50	47	41	47	..	..	
	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	42	..	41	..	41	43	36	38	46	38	51	49	..	52	..	..	
	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	45	..	42	..	41	44	41	45	46	40	51	50	..	55	..	..	
	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	42	..	42	45	45	48	47	41	51	50	..	55	..	..	
	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	43	..	42	47	45	48	51	46	52	50	..	..	..	..	
	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	44	..	43	48	46	50	51	48	52	51	..	..	..	..	
	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	44	..	45	..	48	50	52	49	53	..	..	..	..	..	
	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	46	..	46	..	49	..	53	50	..	..	..	..	..	..	
	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	47	..	46	..	50	..	53	51	..	..	..	..	..	..	
	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	47	..	51	..	53	..	..	..	..	..	..	..	
	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	47	..	..	..	..	..	..	..	..	..	..	..	
	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	48	..	..	..	..	..	..	..	..	..	..	..	

[1] Figures taken from tables on pp. 56 and 57 of 'A Point Scale for Measuring Mental Ability.'

The *coefficient of mental ability*, obtained by dividing a given score by the average for the age and sex group to which the individual belongs, affords the readiest means of stating the mental status of an individual by the point-scale method. The question then is, What coefficient of mental ability (C.M.A.) signifies such mental deficiency as makes it inevitable that the individual will be an expense to others, and a social offender, if allowed at large?

We have referred above to mental traits not comprised in the Yerkes-Bridges point scale, which are determining factors in efficiency and in safeguarding against social offenses. Attachment to persons, ability to foresee the approvals and disapprovals of others, and the impingement of such motives upon behavior, are examples of such factors. However, the point scale gives us a preliminary survey of mental ability, alike for all, and we must try out some C.M.A. as a limit for inefficient mentality. The limit commonly used in the method of right and wrong cases, of seventy-five per cent., is suggested. When absolute chance (an unknown number of unknown factors) prevails, as in flipping pennies, fifty per cent. of each of two possible results ensues. When one constantly operating cause prevails, one hundred per cent. of the looked-for result ensues. Seventy-five per cent. of cases of a given result indicate the elimination of pure chance, and the operation of some fixed operating factors under the conditions prevailing, even though they may be undiscovered. So, until practical experience proves us wrong, we may assume that individuals scoring seventy-five per cent. or less of the average scores of their age groups, are so poorly endowed that they are to be classed as feeble-minded. We name that figure, however, with full consciousness that this practical concept (feeble-mindedness) must be marked off by the point scale, through the practical demonstration of what hundreds of individuals, who prove themselves socially inadequate, do and have scored, by this Yerkes-Bridges point scale, and by yet more thorough and adequate point scales for measuring intelligence. Seventy-five per cent. is merely proposed that we may see how it will work. We give, in addition, in Tables I., II., and V., the 70 per cent. and 80 per cent. levels.

TABLE V

SEX AND AGE GROUPS OF DELINQUENT MINORS TESTED. NUMBERS OF EACH GROUP SCORING (1) AT OR ABOVE YERKES-BRIDGES AVERAGES, (2) 20% OR MORE BELOW THESE AVERAGES, (3) 25% BELOW, AND (4) 30% BELOW. (5) NUMBERS OF FEEBLE-MINDED BY THE YEAR-SCALE MEASUREMENT, AND OF THESE (6) THE NUMBERS WHO SCORE ABOVE YERKES-BRIDGES AVERAGES BY P.S. AND (7) NUMBERS WHO SCORE BY P.S. HIGHER THAN 75% OF YERKES-BRIDGES AVERAGES. (8) NUMBERS OF THOSE WHO ARE NOT FEEBLE-MINDED BY YEAR SCALE, AND YET SCORE LESS THAN 75% OF YERKES-BRIDGES AVERAGES

Yerkes-Bridges Averages to 15, and Norms Assumed from Scores of Mill Operatives, 16 to 19 Years	(62)		(65)		(77)		(79)		(81)		(82)		(84)		(86)		(88)		(88)		Totals	Per Cent.
Age	10		11		12		13		14		15		16		17		18		19			
Sex	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.		
Numbers of individuals examined	12	1	26	2	36	4	58	17	94	45	136	77	112	79	127	68	67	33	3	3	1000	
1. Numbers at or *above* Yerkes-Bridges averages	2	0	7	0	1	1	7	2	11	4	21	12	17	14	12	9	16	4	0	0	140	14.0
2. Numbers *20% below* Yerkes-Bridges averages	2	1	9	0	17	1	27	9	46	22	55	33	38	26	52	30	28	16	2	3	417	41.7
3. Numbers *25% below* Yerkes-Bridges averages	1	1	5	0	11	1	23	6	35	16	40	21	21	19	42	22	14	10	0	3	291	29.1
4. Numbers *30% below* Yerkes-Bridges averages	1	1	2	0	6	1	19	2	24	13	29	14	12	12	28	15	11	9	0	3	202	20.2
5. Numbers feeble-minded by year scales	0	0	0	0	1	1	12	2	37	18	86	39	93	50	110	41	48	19	3	3	563	56.3
6. Numbers feeble-minded by year scales, and above Yerkes-Bridges averages	0	0	0	0	0	0	0	0	0	0	0	0	6	3	4	2	2	0	0	0	17	1.7
7. Numbers feeble-minded by year scales and less than 25% below Yerkes-Bridges averages	0	0	0	0	0	0	0	0	7	4	48	18	72	31	68	22	34	9	3	0	316	31.6
8. Numbers 25% or more below Yerkes-Bridges averages, and not feeble-minded by year scales	1	1	5	0	10	0	11	4	4	2	0	0	0	0	0	0	0	0	0	0	38	3.8

On the whole, a percentage of average mental attainment would seem a much more definite and satisfactory means of stating the mental development of an individual than is that of the years of childhood to which his mentality is equivalent. It gets over the marked unfairness to an adolescent whose four years of retardation are by no means an equivalent to the four years backwardness of an eleven-year-old who tests seven. On the other hand, this latter method has a practical intelligibility which commends it as a means of classifying and conceiving the mental status of imbeciles and low-grade morons, which will probably lead to its retention for a time even in connection with point-scale measurements.

Further, it is yet to be shown by practical studies, how much the actual place of the growing individual in the physical developmental process has to do with his prognosis. It may readily be that twenty-five per cent. deficiency of a seventeen-year-old means an unrecoverable retardation, permanently unfitting him for self management, while in a ten-year-old perhaps a thirty per cent. retardation of mental equipment may be recoverable, because of the greater growth of structure and consequent development of functional capacity, which may lie before him. Certainly *physiological age* must be taken into consideration in making diagnoses and prognoses of boys and girls from eleven to fifteen years of age. The child whose growth has been checked by unfavorable vital conditions has doubtless a fair prognosis when these conditions are made good, even though the mental showing makes him out feeble-minded. Again, in our American cosmopolitan, urban populations, racial antecedents are important factors in determining mental growth. These must be studied and given weight in making prognoses.

Table V. exhibits the incidence of feeble-mindedness, judged by year-scale standards. It will be observed that while five hundred and sixty-three of the thousand delinquents are either four years retarded mentally, or, if sixteen or above, test less than twelve mentally by the Binet or revised year-scale, three hundred and sixteen of these make scores, by the point scale, which are seventy-five per cent. or more of

the Yerkes-Bridges averages for their respective ages. Seventeen of those who are feeble-minded, as judged by these year-scale standards, are even at or above the Yerkes-Bridges averages. This certainly directs suspicion at the year-scale methods of measuring the mental equipment of these adolescents. These seventeen cases all occur among sixteen-, seventeen- and eighteen-year-olds. Point-scale testing serves at least to put over into the class of "doubtfuls" more than half of the feeble-minded delinquents of the reform schools, as these have been previously rated by some examiners. Most likely they are dull and not interested in subjects of formal education.

By assuming a limit of seventy-five per cent. of average performances, as marking off the feeble-minded, we find two hundred and ninety-one, or twenty-nine per cent. of the one thousand subjects, who are feeble-minded by point-scale measurements. Of these, there are thirty-eight—all less than fifteen years of age—who do not fall four years below chronological age in mentality, as measured by year-scales. The place of incidence of this difference indicates that four years retardation is more than twenty-five per cent. retardation in late childhood and pubescence. This it is in fact. Twenty-five per cent. subtracted from any average score in this period gives more than the score of four years earlier. The twenty-five per cent. retardation turned into years, varies from one to three and a half. There are, thus, two hundred and fifty-three, or twenty-five per cent. of all subjects, who are both twenty-five per cent. retarded and either four years retarded or under twelve years mentally if actually sixteen or more years of age. A very large percentage of this group will no doubt prove definitely and permanently feeble-minded by the practical tests of life. They *may* all prove so. Some few outside of this twenty-five per cent. will probably prove feeble-minded by practical testing out. One must, by all means, be conservative in declaring individuals feeble-minded. Great injury is done to the individual, to society, and to this field of practical psychology, by calling feeble-minded any individual who later proves himself capable of

earning his own living and managing himself in an inoffensive manner.

The point scale has furnished an expeditious means of marking off the group among juvenile offenders (relatively much smaller than figures current from many quarters), in which will be found nearly all of those who will prove to be feeble-minded. It prepares the way for psychological clinicians to arrive quickly at close quarters with the problems of the relationship of feeble-mindedness with delinquency, and to help judges and other arms of the social service to deal with the individual offender on the basis of his actual mental capacity, his potentialities for social living, the real stuff that is in him for the making of personality.

The fact that there are so many school children (forty-three in four hundred and sixty-eight) who are twenty-five per cent. or more below the averages for their groups, makes one cautious about expecting all who are twenty-five per cent. retarded to prove feeble-minded. The conditions of retardation and the state of physical development must be weighed in each case.

That only fourteen per cent. (one hundred and forty) of these individuals measure at or above the averages for their age groups, indicates again the heavy incidence of mental abnormality. In connection with the above facts and discussion, this also indicates that over fifty per cent. of the minor delinquents are retarded, peculiar, or subnormal, children and adolescents, who present puzzling problems to the medico-social service. To call them feeble-minded is simply to add to the cloudiness and confusion of the situation, and to stultify this branch of medico-psychological work.

The relationship of the *four years retardation* and the *twenty-five per cent. retardation* to each other, and the distribution of these thousand delinquents with respect to both of these standards and to the average attainments of Cambridge school children are exhibited in Fig. 1. The upper curve is that of average attainment. The next below at the left is that of twenty-five per cent. below average attainment.

The lowest at left is that of four years below average attainment. These last two cross at 13.7 years. For younger children four years retardation is greater than twenty-five per cent. Children older than 13.7 who are twenty-five per cent. retarded are more than four years retarded.

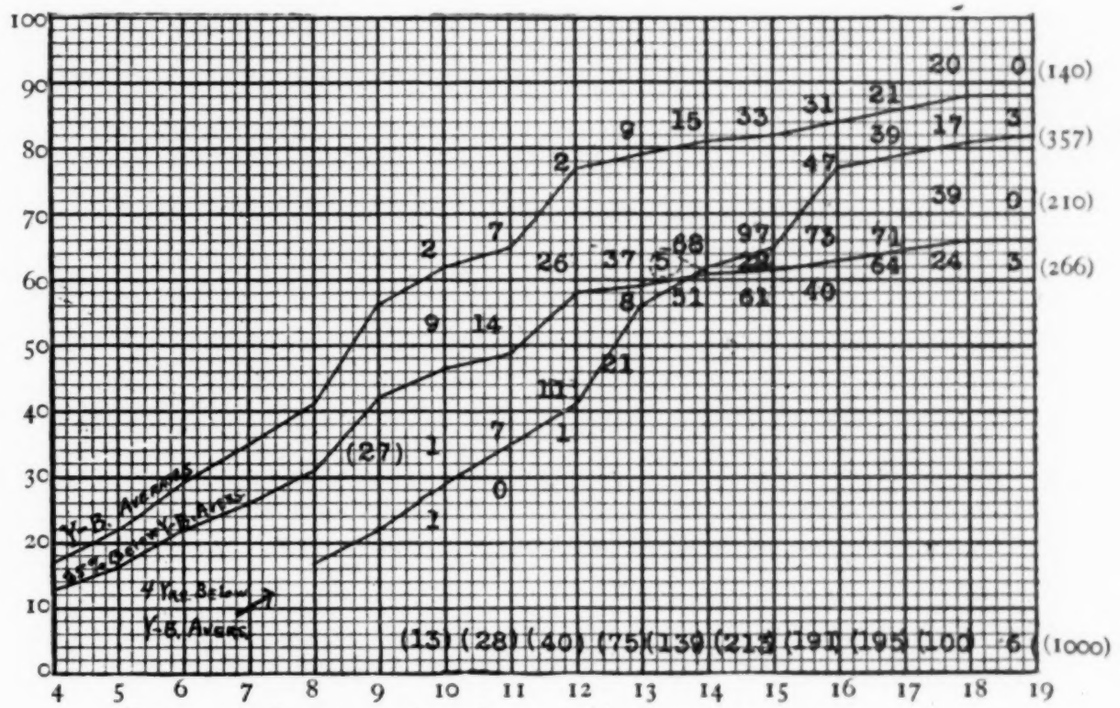

FIG. 1. Ordinates = points of score. Abscissae = age in years.

Upper curve shows the Yerkes-Bridges *average* attainment by years, of children of English-speaking parents.

The curve starting at left next below this, shows the *twenty-five per cent. below average* Y.-B. attainment of children of English-speaking parents.

The curve starting lowest at the left shows the *four years below average* Y.-B. attainments of children of English-speaking parents.

The actual numbers in each group are inserted of those (1) above average (140); (2) retarded less than four years and less than twenty-five per cent. (357); (3) retarded less than four years *but* more than twenty-five per cent. (27); (4) retarded more than four years *but* less than twenty-five per cent. (210); and (5) retarded more than four years and more than twenty-five per cent. (266).

There are fourteen per cent. (140) above average, as noted above; thirty-five and seven tenths per cent. (357) are under average but are neither twenty-five per cent. nor four years retarded; twenty-six and six tenths per cent. (266) are both four years and twenty-five per cent. retarded. Twenty-one per cent. (210) who are fourteen or more in

actual age, test less than twenty-five per cent. retarded but more than four years retarded. This group is a substantial part of the approximately thirty-one per cent. of the thousand (316) who are mentally deficient according to year-scale standards, but are not so if we consider seventy-five per cent. of average point-scale performance as passing for normal. The ten per cent. have slipped over by virtue of the more accurate measuring of the point-scale.

The group of children of thirteen years or less who are not four years retarded but are more than twenty-five per cent. below the average, is small. There are twenty-seven such. This is seventeen per cent. of the total number examined of thirteen years or less. It is therefore about as important a group as that just considered which constitutes twenty-five per cent. of those fourteen or more years of age.

For the present it is important to use the year-scale in addition to the point-scale for children of thirteen years and less. Such children constitute less than one sixth of our reform school population. For the remaining five sixths, of fourteen years or older, we can see no advantage to be derived from a year-scale measurement. For these the point scale is quicker and more informing.

A direct comparison of the results of year-scale (Binet-Simon) and point-scale measurements of five hundred and seventy-one boys is afforded by the two parts of Table VI. The upper part groups the boys by chronological age, and then by retardation, and advancement according to point-scale measurement, within these year groups. All whose mental measurements fall within one half year of the assigned chronological year are classed "at age." Those whose mental age is from 0.6 to 1.5 years lower than assigned age are classed as "testing one year below age." The numbers of individual subjects are given for each of these subgroups. So also are given percentages of the total number in each chronological age group. The same arrangement of numbers and percentages of subgroups of Binet-Simon measurements is given in the lower part of the figure.

It must be borne in mind that we have of necessity ex-

TABLE VI

ABOVE—RELATIONS OF POINT-SCALE MEASUREMENTS OF 571 DELINQUENT BOYS, WHO TEST LESS THAN 12 YRS. BINET-SIMON, TO THEIR CHRONOLOGICAL AGES.

BELOW—RELATIONS OF BINET-SIMON MEASUREMENTS OF THE SAME 571 BOYS TO THEIR CHRONOLOGICAL AGES.

PERCENTAGES AND NUMBERS GIVEN FOR "AT AGE" AND EACH YEAR OF RETARDATION AND ADVANCEMENT.

Point Scale

Chronological Age	Testing Above Age				Testing at Age 0.5— to 0.5+	Testing Below Age										Totals
	4 Yrs. 3.6–4.5	3 Yrs. 2.6–3.5	2 Yrs. 1.6–2.5	1 Yr. 0.6–1.5		1 Yr. 0.6–1.5	2 Yrs. 1.6–2.5	3 Yrs. 2.6–3.5	4 Yrs. 3.6–4.5	5 Yrs. 4.6–5.5	6 Yrs. 5.6–6.5	7 Yrs. 6.6–7.5	8 Yrs. 7.6–8.5	9 Yrs. 8.6–9.5	10 Yrs. 9.6–10.5	
10	...	...	....	17% (2)	25% (3)	50% (6)	....	....	8% (1)	....	....	....	....	....	....	12
11	...	...	....	8% (2)	19% (5)	19% (5)	35% (9)	15% (4)	4% (1)	....	....	....	....	....	....	26
12	...	...	....	....	25% (8)	19% (6)	22% (7)	25% (8)	9% (3)	....	....	....	....	....	....	32
13	2% (1)	...	....	6% (3)	6% (3)	25% (13)	14% (7)	13% (7)	17% (9)	15% (8)	2% (1)	....	....	....	....	52
14	1% (1)	1% (1)	1% (1)	6% (5)	5% (4)	4% (3)	18% (15)	18% (15)	13% (11)	20% (16)	11% (9)	1% (1)	....	....	....	82
15	...	4% (5)	2% (2)	2% (2)	3% (4)	7% (8)	6% (7)	17% (21)	20% (24)	16% (19)	17% (21)	3% (4)	2% (2)	1% (1)	....	120
16	...	1% (1)	....	3% (3)	4% (4)	2% (2)	8% (7)	4% (4)	24% (22)	23% (21)	17% (15)	8% (7)	3% (3)	2% (2)	....	91
17	...	...	....	2% (2)	1% (1)	3% (3)	4% (4)	4% (4)	8% (9)	24% (26)	24% (26)	6% (6)	24% (25)	....	....	106
18	...	...	....	....	6% (3)	6% (3)	....	9% (4)	....	6% (3)	19% (9)	28% (13)	9% (4)	13% (6)	4% (2)	47
19	...	...	....	....	....	....	....	....	....	....	33% (1)	....	67% (2)	....	....	3
Totals	2	7	3	19	35	49	56	67	80	93	82	31	36	9	2	571

Binet-Simon Scale

10	...	...	....	17% (2)	33% (4)	33% (4)	8% (1)	8% (1)	....	....	....	....	....	....	....	12
11	...	...	....	....	27% (7)	27% (7)	31% (8)	15% (4)	....	....	....	....	....	....	....	26
12	...	...	....	....	3% (1)	28% (9)	56% (18)	9% (3)	....	3% (1)	....	....	....	....	....	32
13	...	...	....	....	....	11% (6)	35% (18)	29% (15)	15% (8)	8% (4)	2% (1)	....	....	....	....	52
14	...	...	....	....	....	....	6% (5)	34% (28)	40% (33)	6% (13)	4% (3)	....	....	....	....	82
15	...	...	....	....	....	....	....	14% (17)	34% (41)	33% (40)	15% (18)	3% (4)	....	....	....	120
16	...	...	....	....	....	....	....	....	13% (12)	51% (46)	25% (23)	8% (7)	2% (2)	1% (1)	....	91
17	...	...	....	....	....	....	....	....	....	21% (22)	41% (44)	30% (32)	7% (7)	1% (1)	....	106
18	...	...	....	....	....	....	....	....	....	....	23% (11)	45% (21)	21% (10)	11% (5)	....	47
19	...	...	....	....	....	....	....	....	....	....	....	33% (1)	67% (2)	....	....	3
Totals	...	...	....	2	12	26	50	68	94	126	100	65	21	7	....	571

cluded from this comparison all those subjects who graded twelve years or twelve plus by the Binet-Simon scale. We did not carry these subjects to the limits of their functional capacities. It would manifestly be unfair to compare such figures with the point-scale limits attained by these same individuals. The only effect of the elimination of these data from the table is to make the population under consideration appear more feeble-minded than they are. The two mental measurements of the same five hundred and seventy-one boys are classified in relation to chronological ages in the two parts of the tables.

By the Binet-Simon measurement twelve test "at age" and two one year advanced. By the point-scale measurement thirty-five test "at age," nineteen "one year advanced," three "two years advanced," seven "three years advanced," and two "four years advanced." For those who are retarded, the Binet-Simon scale makes the retardation much greater than the point scale. The absence of "at-age" subjects, measured by the Binet-Simon scale after twelve years, and the regularity of the increase of both minimal retardation and of median positions of retardation, after twelve years, is striking. It is evident the point-scale makes more distinctions and finer differentiations in regard to mental ability than the Binet-Simon scale. The same group of one hundred and six seventeen-year-olds who are measured as five years or more retarded by the Binet year-scale, are distributed from "one year advanced" by the point-scale. There are twenty-three point-scale measurements, of seventeen-year-olds, of less than five years' retardation. If this wider distribution indicates more accurate mental measurement, and we find no facts or arguments to contradict that assumption, we evidently have a better measuring instrument in the point-scale. These differences in point-scale scores point directly to differences in mental capacity. By referring to the individual tests where the differences occur, the examiner can quickly ascertain the species of mental capacity in which a given subject is strong and weak.

Table VII. affords a view of a yet closer juxtaposition of

TABLE VII

RELATIONS BY YEAR STEPS OF THE BINET-SIMON MEASUREMENTS OF THE 571 BOYS OF TABLE VI. TO THE POINT-SCALE MEASUREMENTS OF THE SAME. NUMBERS OF BOYS AND PERCENTAGES GIVEN FOR EACH YEAR OF RETARDATION AND ADVANCEMENT AND AT AGE

Point-Scale Age	Binet *Above* P. S. Age		Binet	Binet *Below* P. S. Age							Totals
	2 Yrs. 1.6 to 2.5	1 Yr. 0.6 to 1.5	At Age. Within 0.5 Yr. of P. S. Age	1 Yr. 0.6 to 1.5	2 Yrs. 1.6 to 2.5	3 Yrs. 2.6 to 3.5	4 Yrs. 3.6 to 4.5	5 Yrs. 4.6 to 5.5	6 Yrs. 5.6 to 6.5	7 Yrs. 6.6 to 7.5	
6	25% (1)	75% (3)	.....	.....	.....	.....	.....	.....	.....	.....	4
7	.....	80% (5)	20% (1)	.....	.....	.....	.....	.....	.....	.....	6
8	.....	54% (22)	44% (18)	5% (1)	.....	.....	.....	.....	.....	.....	41
9	3% (3)	51% (57)	44% (49)	2% (2)	.....	.....	.....	.....	.....	.....	111
10	.....	17% (11)	71% (45)	11% (7)	.....	.....	.....	.....	.....	.....	63
11	.....	.....	42% (63)	56% (83)	2% (3)	.....	.....	.....	.....	.....	149
12	.....	.....	38% (39)	59% (60)	3% (3)	.....	.....	.....	.....	.....	102
13	.....	.....	.....	19% (6)	81% (25)	.....	.....	.....	.....	.....	31
14	.....	.....	.....	.....	38% (5)	62% (8)	.....	.....	.....	.....	13
15	.....	.....	.....	.....	.....	36% (8)	64% (14)	.....	.....	.....	22
16	.....	.....	.....	.....	.....	.....	20% (2)	60% (6)	20% (2)	.....	10
17	.....	.....	.....	.....	.....	.....	.....	50% (4)	50% (4)	.....	8
18	.....	.....	.....	.....	.....	.....	.....	.....	91% (10)	9% (1)	11
Totals.....	4	98	215	159	36	16	16	10	16	1	571

point-scale and Binet year-scale measurements. The Binet ratings of the same five hundred and seventy-one boys of Table VI. are distributed in regard to the point-scale ratings of the same boys. For instance, if a boy scores fifty-six points, the average for nine years, by point-scale, and scores eight and six tenths Binet, he is sorted out as a nine-year-old (P.S.) who tests "at age" by the Binet year-scale. If another boy tested nine years by point-scale and ten and eight tenths Binet, he is classed as a nine-year-old (P.S.) who is two years advanced by Binet measurements. The

point-scale scores are reckoned in each case, as of the nearest year. Fifty-six is the score for nine years, and sixty-two for ten years. Fifty-seven, fifty-eight and fifty-nine were reckoned as nine years, and sixty and sixty-one as ten years. The differences between point-scale and Binet ages were always taken in actual tenths of years. For instance, a score (P.S.) of fifty-eight is equivalent to nine and thirty-three hundredths years. A Binet age ten and eight-tenths years shows an advance of one and forty-seven hundredths years, and is classed as "one year advanced,"—within the limits 0.6 to 1.5 year ahead of point-scale age.

The striking feature of this exhibition (Table VII.) is the fact of change of relationship of the two scales at ten years. At mentalities of ten and below, as estimated by the point-scale, the Binet scale measures a majority of the subjects higher than the point-scale. On the other hand, from mentalities of eleven years and more, the Binet estimates depart by wider and wider differences in the other direction. Subjects testing eleven and above by the point-scale are estimated lower by the Binet scale. Further, they are all estimated about the same by the Binet scale, for as the point-scale age advances, the Binet retardation over point-scale ratings advances. This progression in the amount of retardation of Binet rating as compared with the point-scale rating, and the yearly increase of the retardation with the years' advances of mentality as estimated by the point-scale, is striking evidence of the lack of flexibility and adaptability in the Binet scale for these finer distinctions in regard to mental capacity. It is in close conformity with the breakdown of the Binet scale as shown in the lower part of Table VI.

The swing across the year-scale standard at ten years is in close conformity with the criticism of the Binet scale, as made by Thorndike and Stern, to which we have already referred. Thorndike finds the Binet ratings of normal children as measured by five investigators to fall more and more behind the real ages from eight and nine tenths years onward to thirteen and eight tenths years, inclusive. Similar results are indicated by Miss Hardwick's exhibition of Dr.

Goddard's data.[1] By her showing eleven years is the point where normal children measured by the Binet scale first show a preponderance of retarded individuals. With twelve-year-olds the median position is at two years retardation, with thirteen-year-olds at three years retardation, with fourteen-year-olds at four years, and with fifteen-year-olds at six years. Our criticisms of the Binet-Simon measuring scale are quite in line with these investigators. Our data reënforce the need of a more accurate means of measuring mental capacity, and augment the arguments and demonstrations already made for the point-scale, that it is more accurate as well as more expeditious, and is constantly perfecting itself as more data are accumulated.

That it is a relatively simple matter to make a year scale which measures mental ability more accurately is shown by Table VIII., where the year-scale findings from the examinations by our revised scale of one hundred and seventy-four delinquent girls are correlated with the point-scale results from the same girls. The method of making estimates is exactly as outlined above for the construction of Table VII.

By these results, it is evident the revised year-scale measurements of mental ages, from seven to thirteen years, inclusive, are very close to those of the point scale. In nearly every one of these point-scale years the median year-scale rating falls within the "at age" group, that is, within six months either way of the point-scale rating. There are only eight cases out of these one hundred and thirty-nine (seven to thirteen years, P.S., inclusive) whose year-scale estimates scatter two years from the point-scale ratings. This, compared with the showing of the Binet ratings of boys of Table VII., is good evidence that progress has been made in this revision, in replacing tests, for the years up to thirteen, in accordance with the facts of mental development. This statement is not based solely upon these comparisons of Binet and revised year-scale findings, with the point-scale findings; it is based upon these comparisons,

[1] See Table *A*, p. 40, 'A Point Scale for Measuring Intelligence,' Yerkes, Bridges & Hardwick.

TABLE VIII

RELATIONS OF THE REVISED YEAR-SCALE (BUREAU OF JUVENILE RESEARCH) MEASUREMENTS TO THE POINT-SCALE AGES OF 174 DELINQUENT GIRLS, STATED IN NUMBERS OF INDIVIDUALS IN EACH "AT AGE" AND "RETARDED" AND "ADVANCED" YEAR, AND PERCENTAGES OF THE TOTAL FOR EACH POINT-SCALE YEAR OF AGE

Point Scale Age	Revised Year Scale *Above* Point Scale		V.S. at Age with P.S.	Revised Year Scale *Below* Point Scale					Totals
	2 Yrs. 1.6–2.5	1 Yr. .6–1.5	0.5— to 0.5+	1 Yr. .6–1.5	2 Yrs. 1.6–2.5	3 Yrs. 2.6–3.5	4 Yrs. 3.6–4.5	5 Yrs. 4.6–5.5	
5	.....	1	.....	.....	.....	.....	.....	.....	1
6	.....	.....	.....	.....	.....	.....	.....	.....	.....
7	.....	.....	75%	25%					
			3	1	.....	.....	.....	.....	4
8	.....	23%	62%	15%					
		3	8	2	.....	.....	.....	.....	13
9	.....	36%	60%	4%					
		9	15	1	.....	.....	.....	.....	25
10	.....	17%	59%	24%					
		3	10	4	.....	.....	.....	.....	17
11	2%	12%	46%	37%	2%				
	1	5	19	15	1	.....	.....	.....	41
12	4%	12%	46%	38%					
	1	3	12	10	.....	.....	.....	.....	26
13	.....	23%	23%	23%	31%				
		3	3	3	4	.....	.....	.....	13
14	.....	.....	.....	75%	25%				
				3	1	.....	.....	.....	4
15	.....	.....	.....	22%	22%	56%			
				2	2	5	.....	.....	9
16	.....	.....	.....	.....	29%	43%	14%	14%	
					2	3	1	1	7
17	.....	.....	.....	33%	.....	.....	67%		
				1	.....	.....	2	.....	3
18	.....	.....	.....	.....	.....	45%	27%	27%	
						5	3	3	11
Totals..	2	27	70	41	11	13	6	4	174

taken in connection with the findings of Hardwick and Thorndike. They find the Binet scale underestimates normal children above nine years. We find the Binet scale underestimates mixed groups of normal and subnormal as measured by the point scale. Thus the point-scale findings are shown to be in close conformity with the facts of mental development. The revised year-scale findings, being in much closer harmony with the point-scale findings, are therefore in closer conformity with the facts of mental development than those of the Binet scale.

For the years beyond thirteen, where all agree there is

very little development, from year to year, of the kinds of mental functions measured by any of these scales, the small number of cases already examined (thirty-three) indicate likewise a closer approximation to the point-scale findings. It will be recalled that Yerkes and Bridges give us no norms beyond fifteen, and for fifteen the number of cases averaged is small. We cannot argue much about the fine distinctions between mental capacities of these delinquent adolescents until we have large accumulations of data concerning the mental capacities of non-delinquent adolescents having similar educational disadvantages.

An outline of the revised year scale is presented herewith. As stated above, our indebtedness to Terman is very large. We adhered to the five-tests-to-a-year plan of Binet, but adopted the fourteen, sixteen and eighteen year tests and many changes of place, within the scale, of Binet-Simon tests. With the recognition that our advanced tests need more advancing to make them conform to the facts of development, we present the outline of our test sheet from which the results of Table VIII. were obtained.

YEAR III

1. Pictures. Enumeration.
2. Names key, penny, closed knife, watch, pencil.
3. Gives last name.
4. Points to nose, eyes, mouth, hair.
5. Gives sex. (Note form of question.)

YEAR IV

1. Compares lines.
2. Copies square.
3. Counts four pennies.
4. Repeats three digits. (1 of 3. Order correct.)
5. Comprehension. First degree. (2 of 3.) "What ought you to do?"
   (*a*) "When you are sleepy?"
   (*b*) "When you are cold?"
   (*c*) "When you are hungry?"

YEAR V

1. Comparison of weights. (Point Scale No. 3. 2 of 3.)
2. Definitions. (Use, or better. 3 of 4.)
3. Æsthetic comparisons. (No error.)
4. Three commissions. (No error, order correct.)
5. Cube test. (One line correct of *X* and *Y*.)

Year VI

1. Mutilated pictures. (3 of 4.)
2. Counts 13 pennies. (1 of 2 trials without error.)
3. Coins. (3 of 4 presented in this order; penny, nickel, dime, quarter.)
4. Right and left. (3 of 3, or 5 of 6.)
5. Cube test. (1 correct, of lines *B*, *C*, and *D*.)

Year VII

1. Repeats five digits. (1 of 3. Order correct. Read 1 per second.)
2. Pictures, description or better.
3. Gives differences. (2 of 3.)
4. Ties bow knot. (Model shown 60 seconds.)
5. Cube test. (2 correct of *B*, *C*, and *D*.)

Year VIII

1. Copies diamond. (Pen. 2 of 3.)
2. Counts 20–0. (40 seconds. 1 error allowed.)
3. Comprehension. (Third degree. 2 of 3.)
   "What's the thing for you to do,"
   (*a*) "When you have broken something which belongs to someone else?"
   (*b*) "When you notice on your way to school that you are in danger of being tardy?"
   (*c*) "If a playmate hits you without meaning to do it?"
4. Repeats three digits backwards. (1 of 3. Read 1 per second.)
5. Ball and field. (Inferior plan.)

Year IX

1. Definitions, superior to use. (3 of 5. "Thing" as genus counts plus.)
2. Suggestion. (2 of last 3 "equal" or "left greater.")
3. Three words in one sentence, or two coördinate clauses.
4. Gives date. Error of three days in date allowed. Day of the week, the month and year exact.
5. Stamps. (Gives total value. Second trial if individual values are known.)

Year X

1. Weights. (6, 9, 12, 15, 18 gm. No illustration.)
2. Repeat six digits. (1 of 3. Order correct. Repeat 1 per second.)
3. Names months.
4. Makes change. (2 of 3. Coins not used. 10 − 6, 15 − 12, 25 − 4 .)
5. Cube test. (1 correct of lines *E*, *F*, and *G*.)

Year XI

1. Designs. (One correct, other half-correct.)
2. Absurdities. (4 of 5. P. S. No. 17.)
3. Sixty words. (Illustrate with star, man, hat, and candy.)
4. Comprehension. (3 of 4. Point Scale No. 15.)
5. Repeats 20–22 syllables. (1 of 3 correct, or 2 with 1 error each.)
   (*a*) "The apple tree makes a cool pleasant shade on the ground where the children are playing."
   (*b*) "It is nearly half-past one o'clock; the house is very quiet and the cat has gone to sleep."

(*c*) "In summer the days are very warm and fine; in winter it snows and I am cold."

YEAR XII

1. Defines, (2 of 3) obedience, charity, justice.
2. Disarranged sentences. (2 of 3. 1 minute each.)
3. Ball and field. (Superior plan.)
4. Repeats five digits backwards. (1 of 3. Read 1 per second.)
5. Similarities—three things. (3 of 5.) "In what way are the following alike":
   (*a*) Snake, cow, sparrow.
   (*b*) Book, teacher, newspaper.
   (*c*) Wool, cotton, leather.
   (*d*) Knife-blade, penny, piece of wire.
   (*e*) Rose, potato, tree.

YEAR XIV

1. Pictures. Interpretation.
2. Repeats seven digits.
3. Reverses hands of clock. 6:22 = 7:03 = (1 of 2. 3 minutes error allowed.)
4. Induction test. 1 — 2 — 3 — 4 — 5 — 6 —. (Gets rule by sixth folding.)
5. Problem of enclosed boxes. (2 of 3.)

YEAR XVI

1. Vocabulary. (60–10,800.)
2. Fables. (3½ credits.)
3. President and King. (Power, accession, tenure. 2 of 3.)
4. Arithmetical reasoning. (2 of 3. 1 minute each.)
5. Difference between abstract pairs. (3 real contrasts out of 5.)

YEAR XVIII

1. Vocabulary. (75–13,500.)
2. Code. Writes "Come quickly." (2 errors allowed.)
3. Repeats eight digits. (1 of 3. Order correct. Read 1 per second.)
4. Paper-cutting test. (Draws, folds and locates holes.) Give before XIV., No. 4.
5. Ingenuity test. (2 of 3. Five minutes each.)
   (*a*) 3 and 5-pint vessel to get 7 pints. (Begin with 5-pint.)
   (*b*) 5 and 7-pint vessel to get 8 pints. (Begin with 5-pint.)
   (*c*) 4 and 9-pint vessel to get 7 pints. (Begin with 4-pint.)

SUMMARY

1. By Binet-Simon scale measurements, fifty-six per cent. of one thousand juvenile delinquents are feeble-minded. Such results and declarations are stultifying the work of clinical psychologists.

2. By Yerkes-Bridges point-scale measurements, chronological year groups of the same juvenile delinquents yield considerably lower averages than Cambridge school children.

3. They also show larger numbers who fall twenty-five

per cent. below their own averages, than twenty-five per cent. above the same averages.

4. As compared with the averages of Cambridge school children, these delinquents yield only about twelve per cent. at or above the normal standards.

5. About twenty-five per cent. are twenty-five per cent. below the normal standards, or have coefficients of mental ability of 0.75 or less. Such a standard eliminates about half of the feeble-minded group set apart by uncritical application of Binet standards. There is no more reason for considering these three hundred delinquents feeble-minded, than there is to denominate large numbers of productive laborers in the community high-grade morons. These delinquents test slightly under twelve years through inefficiency of the Binet scale.

6. By comparison of the Binet and point-scale ratings of five hundred and seventy-one boys with each other, the point scale is shown to be a much finer measuring instrument. By this scale one can point out much more definitely the mental capabilities which are above and below normal. It is the rational procedure for beginning an analysis of character. Upon this basis one can more safely make recommendations for treatment and prognosticate the future of the individual.

7. The Binet scale, compared with the point-year scale, breaks down in the examination of all persons of mental ages over ten years, very much as other investigators have shown it does with normal children. It underestimates mentality more and more from ten years onward. It likewise overestimates below eight years.

8. A revised year-scale adopted largely from Terman, corrects these defects of the Binet scale, to a great degree, for mentalities up to fourteen years. For fourteen, sixteen and eighteen years our tests need toning down. They are too advanced for the years to which they are assigned.

9. For these finer differentiations of mental capacity, and especially the traits and functions characteristic of the period of adolescence, the development of the point-scale offers a procedure at once more efficient and more pliable.